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RELATING TO

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IV.—THE HOT WINDS OF NORTHERN INDIA.
V.—AN ACCOUNT OF A STORM DEVELOPED IN EQUATORIAL REGIONS.

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IV.—The Hot Winds of Northern India, by J. ELIOT, M.A., F.R.S., *Meteorological Reporter to the Government of India.*

The subject of the hot winds of the Gangetic Plain of Northern India has been discussed by the late Messrs. Blanford and Hill and by Mr. F. Chambers.

Mr. Blanford first considered them to be due to what he termed "elastic expansion," following up a suggestion of Professor Laughton in his work entitled "Physical Geography in its relation to the prevailing winds and currents," but afterwards adopted a' theory similar to that suggested by Mr. Hill (in his paper* on "Some anomalies in the winds of Northern India and their relation to the distribution of barometric pressure") *viz.*:—that hey are due to rapid convective actions in the hot weather, by which the slow moving masses of air near the earth surface are carried upwards and replaced by more rapid-moving masses of air from above. This explanation was first suggested in a paper of Köppen's in the *Meteorologische Zeitschrift.* Hill concluded from an examination of the charts giving mean pressure, &c., and also from the daily weather data published in the India Daily Weather Reports, that these winds were characterized by several noteworthy features which appeared to be opposed to the ordinary relations that subsist between air movement in the horizontal direction and the accompanying pressure gradients.

The following is a summary of Hill's views given, so far as possible, in his own words. He states:—

First.—"The direction of the wind in the hot season in the plains of Northern India has often no relation to the baric gradients; instances not infrequently occurring in which the wind appears to blow in direct opposition to the gradient, *i.e.*, from a place of low pressure to one where the barometer stands higher."

Second.—"Over the plains of Northern India the velocity of the wind in the hot season has usually little or no apparent relation to the pressure gradient, but a very obvious one to the temperature, being, on the whole, greatest when the temperature is highest."

He further says: "These westerly winds of the hot weather are so dry perhaps because they descend from regions where the proportion of water vapour in the air is normally much less than that at sea-level. The diurnal interchange between the lower atmospheric strata and those lying considerably higher was first suggested by Dr. Köppen to explai certain daily inequalities of wind direction and velocity—inequalities which are opposite in phase over plains and on high mountain peaks. This diurnal interchange probably suffices to clear up all the anomalies observed in the wind system of India. The explanation of the dryness of these winds by the descent of air from a higher stratum was previously suggested by Mühry in a passage quoted by Blanford at page 614 of his paper on the "Winds of Northern India," but this was under the mistaken notion of an aërial cascade pouring over the edge of the Himalayas from the elevated plains of Thibet, a notion which is quite inconsistent with the facts of observation."

*Philosophical Transactions of the Royal Society of London, Vol. 178 (1887), A, pp. 335-378.

Hill based his statements of the peculiar pressure relations accompanying the hot winds, not merely on mean monthly pressure data, but also on the actual pressure distribution of single days, as shown by the daily weather reports and charts, which, as he says, "leave no room for doubt that almost every year there are several days in April, May and June when the *primâ facie* impossible conditions (*viz.*, that the winds blow directly against the baric gradients) obtain over a large extent of country in Northern India."

He also states that an examination of the diurnal variations of humidity and cloud naturally suggests the idea of an interchange between the upper and lower strata by local convection currents.

Although I am not prepared to assert that the large convective movements of the hot weather do not contribute in the manner indicated by Messrs. Blanford and Hill to the day movement in the Gangetic Plain, the explanation that it is the primary or only cause has not appeared to me either satisfactory or sufficient.

In the first place Hill's statement assumes that the pressure relations indicated by the 8 A.M. or 10 A.M. daily weather charts are practically based on simultaneous observations and give the gradients which subsist at a definite instant of time.* In the second place, it assumes, as an explanation, actions (*i.e.*, convective movements due to large and rapid temperature changes during the day) which are not restricted to the hot weather, but which are probably exhibited to some extent at least in the cold weather months as well as in the hot weather. There are other minor difficulties in the explanation, in addition to the following important theoretical difficulty. These winds are weakest, as far as my experience indicates, in the western districts of the Gangetic Plain, and strongest in the eastern districts, and hence increase in intensity in the horizontal direction. If this air movement were due solely to the cause assigned by Hill, then the velocity should either apparently be fairly uniform over the whole area, or the descending air masses should come from very different elevations in the different parts of the Gangetic Plain, of which there is no suggestion in Hill's paper, and for which it would be very difficult to assign an adequate cause.

The following is a brief statement of the chief features of the air movement in the Gangetic Plain in the hot weather months of March, April and May :—

The air movement in the hot weather is usually feeble during the night hours and varies very little from 6 or 7 P. M. up to 8 A. M. It then increases rapidly up to about 1 or 2 P. M., and occasionally, when conditions are most favourable, blows almost with the force of a gale during the next two or three hours, after which it falls off again very rapidly until 6 or 7 P.M., when the wind is light and nearly calm.

These winds, it may be noted, blow from directions between west and north-west, and there is little shift of direction during the day hours.

The most characteristic features of the hot winds, *i.e.*, of the westerly winds of the hot weather season in Northern India, are their intense dryness and excessive temperature. These are chiefly a product of the general meteorological conditions of the period.

The humidity occasionally falls to as low as 2 or 3 per cent. from noon to 4 P.M. on the days when the hot winds are most vigorous. The maximum temperatures in the Gangetic Plain on the days when they blow most strongly range usually between 105° and 115°.

It may be further noted that these winds raise clouds of dust with which the whole

* This remark only applies to the preceding statements in question. Hill in his paper works out the pressure differences in May at two places 15° of longitude distant in Northern India, so far as they are dependent only on the diurnal variations.

ower atmosphere becomes surcharged, and which give a peculiar reddish yellow glare o the sunlight, more especially in the afternoon hours.

The preceding has given a brief sketch of the chief features of the hot winds in heir most marked form. The hot winds of the Gangetic Plain have been too frequently *reated* as forming a unique system. We first propose to show that in all their more mportant features they are practically identical in character with the winds of the cold veather months in Northern India and are, in fact, their continuation, their increasing lryness and higher temperature in March, April and May being due to the climatic conlitions of the period.

The air movement in the Gangetic Plain in December, January and February forms in integral part of the cold weather or ordinary north-east monsoon circulation in Southern Asia and the adjacent seas, and is most strongly developed in the month of *January* when the gradients for the prevalence of winds of continental origin in Southern Asia and the Indian seas are strongest, and hence, in this paper, the winds of January are aken as the type of the cold weather circulation.

The most remarkable feature of the hot winds is (*vide* Hill's paper) that, judging rom the mean pressure distribution of the period, they prevail during a period of ery slight gradients (in fact of almost uniform pressure) in the Gangetic Plain. These eatures, as will be shown below, obtain on the mean of the whole month most markedly in April and May, and hence these two months are selected in this memoir as the periods most epresentative of the pressure conditions accompanying the hot winds of Northern India.

The following table gives mean 8 A.M. pressures for the months of March, April and May at stations in the Indo-Gangetic Plain:—

TABLE I.

Station.	Mean 8 A.M. (local time) pressure reduced to sea-level and constant gravity at lat. 45° in the months of		
	March.	April.	May.
	"	"	"
Lahore	29·902	29·744	29·602
Sirsa	·898	·742	·605
Delhi	·892	·740	·617
Roorkee	·890	·739	·628
Meerut	·881	·733	·618
Lucknow	·878	·737	·636
Allahabad	·882	·741	·634
Sutna	·900	·750	·620
Benares	·878	·738	·636
Patna	·875	·743	·658
Purnea	·864	·754	·690
Hazaribagh	·878	·744	·644
Sambalpur	·861	·745	·642

The data of the preceding table indicate that the mean 8 A.M. (local time) pressure is in March about ·03″ higher in the Punjab than it is in Chota Nagpur and Bihar, and that in May it is about ·04″ lower in the Punjab than in Bihar. The data hence suggest that there are feeble gradients for westerly winds in March and feeble gradients for easterly winds in May. The mean 8 A.M. pressure values in the intermediate month of April are almost identical in amount for all the stations for which data are given, thus indicating that the mean pressure gradients for the month in the direction of the Gangetic Plain (*i.e.*, in either a westerly or easterly direction) are practically *nil*.

The following table gives corresponding data (taken from the Report on the Meteorology of India for the year 1890) of the mean daily pressure at 13 stations in Northern India for these months as determined from the 10 and 16 hours' observations:—

TABLE II.

Station.	Mean daily pressure reduced to sea-level and constant gravity in the months of		
	March.	April.	May.
	″	″	″
Lahore	29·862	29·716	29·574
Sirsa	·860	·711	·574
Delhi	·835	·700	·577
Roorkee	·834	·684	·576
Bareilly	·824	·684	·582
Lucknow	·831	·692	·592
Allahabad	·822	·687	·581
Sutna	·830	·691	·573
Benares	·828	·692	·586
Patna	·816	·691	·601
Purnea	·807	·694	·634
Hazaribagh	·824	·693	·596
Sambalpur	·790	·667	·567

The mean pressure values for these months given in Table II indicate that in March there are moderate gradients for westerly winds in the Gangetic Plain, and in April feeble gradients, whereas in May pressure is approximately uniform, but varies somewhat irregularly from absolute uniformity in different parts of the Indo-Gangetic Plain.

The data of this table hence show that the mean daily pressure for the month of May is almost as uniform as the 8 A. M. (local time) pressure of April over the whole Gangetic Plain. It hence follows that either of the months of April or May may be selected as exhibiting the pressure conditions characteristic of the period of the hot winds in Northern India.

The following table gives the differences of pressure or total barometric gradients in different parts of the Gangetic Plain during the months of March, April and May, first as

determined from the 8 A. M. mean pressure data, and secondly as derived from the mean daily pressure data for these months :—

TABLE III

	Month.	Total baric gradient.			
		Allahabad to Patna (310 miles.)	Delhi to Allahabad. (350 miles.)	Lahore to Delhi. (270 miles.)	Lahore to Patna. (800 miles.)
		"	"	"	"
8 A.M. local time	March	+·007	+·010	+·010	+·027
	April	—·002	—·001	+ 004	+·001
	May	—·024	—·017	—·015	—·056
Mean of day	March	+·006	+ 013	+·027	+·046
	April	—·004	+·013	+·016	+·025
	May	—·020	—·004	—·003	— 027

The table shows that the gradients are very small in amount, and that they differ considerably according to the two methods of their computation.

In the remainder of the paper we shall give data chiefly for April, selecting it as, on the whole, most representative of the hot weather conditions in the Gangetic Plain (*i.e.*, the South-East Punjab, North-Western Provinces and Bihar).

We now proceed to determine the chief features of the mean air movement in the Gangetic Plain and Northern India generally during the cold weather and hot weather seasons.

In Table IV are given data of the mean air movement, as registered by Robinson anemometers for the months of January to May, for 19 stations in Northern India, at which the exposure of the anemometers is most satisfactory and the observations have been most carefully taken.

TABLE IV.—*Mean daily air movement of the months of January to May at 10 stations.*

Area.	Station.	Mean daily air movement in miles.				
		January.	February.	March.	April.	May.
Gangetic Plain . . .	Lahore . . .	45	57	73	80	79
	Ludhiana . . .	30	41	46	52	56
	Roorkee . . .	51	68	70	76	88
	Meerut . . .	50	61	63	60	63
	Lucknow . . .	57	78	97	106	102
	Agra	82	97	108	114	139
	Allahabad . . .	50	70	74	86	99
	Darbhanga . . .	59	88	113	138	145
	Patna	48	71	84	108	118
Bengal	Burdwan . . .	43	52	79	114	131
	Berhampore . . .	43	56	82	124	132
	Calcutta . . .	68	85	125	175	172
	Saugor Island . .	151	189	205	401	367

TABLE IV.—*Mean daily air movement of the months of January to May at 19 stations*—concld.

Area.	Station.	Mean daily air movement in miles.				
		January.	February.	March.	April.	May.
Assam	Dhubri	93	95	151	192	168
	Sibsagar	43	51	66	67	66
Rajputana and Central India.	Jeypore	91	104	128	133	159
	Sutna	100	116	137	168	198
	Raipur	67	93	118	150	190
Chota Nagpur	Hazaribagh	118	156	178	201	210

The anemometric returns for these stations show that over the Indo-Gangetic Plain and the interior of Bengal the air movement in January ranges between 2 and 4 miles per hour, and increases at all stations during the next three or four months to the maximum movement of the year, which occurs either in April or May in the Gangetic Plain. The mean velocity data in Table IV are taken from Table XXI of the Annual Report for 1890, or Table IX, Appendix of the Annual Report for 1886.

In the following table the preceding data are given in a form which shows more clearly the gradual increase of velocity during the whole period. In order to eliminate differences of exposure, the velocity of January is assumed as the unit for each station, and the velocity of the air movement in other months is expressed as the ratio of the movement of the month to that of January.

TABLE V.—*Ratio of wind velocity in each of the months February to May to that of January.*

Area.	Station.	Ratio of mean daily air movement of month to that of January			
		February.	March.	April.	May.
Gangetic Plain	Lahore	1·3	1·6	1·8	1·8
	Ludhiana	1·4	1·5	1·7	1·9
	Sirsa	1·3	1·4	1·6	1·8
	Meerut	1·3	1·3	1·2	1·3
	Roorkee	1·3	1·3	1·5	1·7
	Lucknow	1·4	1·7	1·9	1·8
	Agra	1·2	1·3	1·4	1·7
	Allahabad	1·4	1·5	1·7	2·0
	Darbhanga	1·5	1·9	2·3	2·5
	Patna	1·5	1·8	2·3	2·5
Bengal	Burdwan	1·2	1·8	2·7	3·0
	Berhampore	1·3	1·9	2·9	3·1
	Calcutta	1·3	1·8	2·6	2·5
	Saugor Island	1·3	2·0	2·7	2·4

TABLE V.—*Ratio of wind velocity in each of the months February to May to that of January*—concld.

Area.	Station.	Ratio of mean daily air movement of month to that of January.			
		February.	March.	April.	May.
Assam	Dhubri	1·0	1·6	2·1	1·8
	Sibsagar	1·2	1·5	1·6	1·5
Rajputana and Central India	Jeypore	1·1	1·4	1·5	1·7
	Sutna	1·2	1·4	1·7	2·0
Chota Nagpur and Central Provinces.	Jubbulpore	1·2	1·4	1·6	2·1
	Hazaribagh	1·3	1·5	1·7	1·8
	Sambalpur	1·1	1·3	1·7	2·0

The preceding data show clearly that there is a fairly regular increase of velocity from January to April and May and which, as remarked by Hill, corresponds to the increasing intensity of the thermal conditions in Northern India during the period. This increase is not uniform over the whole of the Gangetic Plain. It is greatest in West Bengal, Bihar and the eastern districts of the North-Western Provinces. The results, it may be pointed out, are quite consistent, and indicate clearly that the central area of the greatest increase of velocity due to the increasing heat of Northern India during the period is Bihar and West Bengal.

One of the most noteworthy features of the air movement in the Gangetic Plain is the large diurnal variation throughout the whole of the cold and hot weather. The hourly observations taken at Calcutta, Hazaribagh, Patna, Lucknow, Agra, Roorkee and Lahore enable a comparison of the diurnal variation of the air movement to be made for these stations for the months of January and April. In the following two tables are given data of the mean hourly air movement during the mean day of the month of January and of April for these seven stations:—

TABLE VI.—*Shewing the mean hourly movement in the month of January at seven stations in Northern India.*

Hours.	Calcutta.	Hazaribagh.	Patna.	Lucknow.	Agra.	Roorkee.	Lahore.
	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.
0 to 1	1·7	2·9	1·7	2·3	3·1	0·9	0·7
1 „ 2	1·7	2·9	1·7	2·4	3·1	1·0	0·7
2 „ 3	1·5	3·0	1·7	2·3	3·0	0·9	0·8
3 „ 4	1·6	3·1	2·0	2·5	3·1	1·0	0·8
4 „ 5	1·7	3·3	2·0	2·4	3·1	1·0	0·9
5 „ 6	1·7	3·7	2·0	2·3	3·1	1·0	0·9
6 „ 7	1·6	3·4	2·0	2·2	3·1	1·0	1·0
7 „ 8	1·8	3·5	2·0	2·1	3·1	0·9	·0
8 „ 9	2·5	5·2	1·9	2·3	3·2	1·0	2·3
9 „ 10	3·5	7·0	2·8	2·9	4·9	1·3	2·3
10 „ 11	4·1	8·3	2·9	3·8	5·0	2·1	2·4

TABLE VI.—*Showing the mean hourly movement in the month of January at seven stations in Northern India*—concld.

Hour.	Calcutta.	Hazaribagh.	Patna.	Lucknow.	Agra.	Roorkee.	Lahore.
	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.
11 to 12	3·9	8·3	2·9	4·4	5·0	2·8	2·4
12 „ 13	4·3	8·7	2·6	5·1	6·0	3·5	2·9
13 „ 14	4·2	8·9	2·6	5·2	6·0	3·4	2·9
14 „ 15	3·9	8·6	2·7	5·0	6·1	3·1	3·0
15 „ 16	3·2	8·2	2·4	4·5	3·8	2·9	3·0
16 „ 17	2·8	7·4	2·4	3·1	3·8	1·8	0·9
17 „ 18	1·7	5·1	2·3	2·2	3·9	1·0	1·0
18 „ 19	1·6	4·0	1·7	2·3	2·8	0·9	1·0
19 „ 20	1·7	3·7	1·7	2·1	2·8	0·9	1·0
20 „ 21	1·9	3·2	1·7	2·2	2·8	0·9	0·5
21 „ 22	2·1	2·7	1·6	2·3	2·0	0·9	0·5
22 „ 23	2·1	2·5	1·6	2·3	2·0	1·0	0·5
23 „ 0	2·0	2·6	1·5	2·3	2·1	1·0	0·4
Mean hourly velocity	2·5	5·0	2·1	2·9	3·6	1·5	1·4
Minimum velocity during day	1·5	2·5	1·5	2·1	2·0	0·9	0·4
Maximum velocity during day	4·3	8·9	2·9	5·2	6·1	3·5	3·0
Ratio of maximum to minimum velocity	2·9	3·6	1·9	2·5	3·1	3·9	7·5

TABLE VII.—*Mean hourly movement in the month of April at seven stations in Northern India.*

Hour.	Calcutta.	Hazaribagh.	Patna.	Lucknow.	Agra.	Roorkee.	Lahore.
	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.	Miles.
0 to 1	6·1	6·1	2·8	4·0	3·1	1·4	2·3
1 „ 2	5·8	6·1	2·8	4·0	3·1	1·0	2·3
2 „ 3	5·5	5·8	2·9	4·0	3·2	1·0	2·3
3 „ 4	5·0	6·0	3·3	3·7	3·6	1·1	2·3
4 „ 5	4·7	6·3	3·3	3·7	3·6	1·0	2·0
5 „ 6	5·0	6·4	3·3	3·7	3·6	0·9	2·0
6 „ 7	5·8	7·0	4·4	3·9	4·4	0·9	2·0
7 „ 8	7·7	10·4	4·4	4·5	4·4	0·9	2·1
8 „ 9	8·2	10·4	4·4	5·7	4·5	2·0	3·8
9 „ 10	8·8	10·4	5·2	7·2	6·8	3·2	3·8
10 „ 11	9·2	11·5	5·2	8·2	6·8	4·8	3·8
11 „ 12	8·9	11·6	5·2	8·5	6·8	5·4	3·9
12 „ 13	9·0	12·8	5·5	8·8	9·0	5·6	4·4
13 „ 14	9·5	13·3	5·5	9·1	9·0	6·0	4·5

TABLE VII.—*Mean hourly movement in the month of April at seven stations in Northern India*
—concluded

Hour.	Calcutta.	Hazaribagh.	Patna.	Lucknow	Agra.	Roorkee	Lahore.
	Miles	Miles.	Miles	Miles	Miles	Miles	Miles
14 to 15 . . .	9·5	13·7	5·6	9·5	9·1	6·2	4·5
15 " 16 . . .	9·9	13·4	5·0	9·6	7·2	6·5	4·5
16 " 17 . . .	10·2	11·7	5·0	8·5	7·2	6·3	2·3
17 " 18 . . .	9·4	10·7	5·0	6·5	7·3	5·2	2·3
18 " 19 . . .	9·4	6·4	3·4	4·8	4·3	3·2	2·3
19 " 20 . . .	9·2	4·7	3·4	4·0	4·3	2·3	2·2
20 " 21 . . .	8·5	4·8	3·4	3·9	4·4	2·0	2·1
21 " 22 . . .	8·0	5·6	2·9	3·6	3·6	1·9	2·1
22 " 23 . . .	7·3	5·9	2·9	3·7	3·6	1·5	2·1
23 " 0 . . .	6·6	5·8	2·9	4·1	3·7	1·5	2·0
Mean hourly velocity . . .	7·8	8·6	4·1	5·7	5·3	3·0	2·8
Minimum velocity during day . .	4·7	4·7	2·8	3·6	3·1	0·9	2·0
Maximum velocity during day .	10·2	13·7	5·6	9·6	9·0	6·5	4·5
Ratio of maximum to minimum velocity	2·2	2·9	2·0	2·7	2·9	7·2	2·3

The preceding data for January and April are plotted in Plate XXVI. The curves in that plate show at a glance the chief features of the diurnal variation of the air movement at the seven stations.

The data of Tables VI and VII, it should be stated, are not strictly comparable. In the case of Calcutta, Hazaribagh and Lucknow the mean hourly velocities are the actual means of a series of hourly observations, but in the case of the remaining stations the hourly means are the results of interpolation applied to the means of observations taken at four hourly intervals, beginning at midnight.

Table VI indicates that the diurnal air movement in the Gangetic Plain in the cold weather season (represented by the month of January), has a marked periodicity. The following gives the chief features:—

(1) The air movement is almost uniform during the night period from 6 or 7 P.M. to 7 or 8 A.M. There is a very slight tendency for the lowest velocities to occur at the beginning and end of this period *e.g.*, at about 7 P.M. and 7 A.M.

(2) The air movement increases very rapidly in intensity from 8 A.M. to noon, and is thence nearly constant until about 3 P.M.

(3) The air movement decreases rapidly from 3 P.M. to 7 P.M.

The following are the chief features of the diurnal variation of the air movement in the Gangetic Plain in April:—

(1) The air movement is almost constant in amount from 9 P.M. to 7 A.M

(2) It increases rapidly in velocity from 9 A.M., until noon or 1 P.M. and attains its maximum between 2 P.M. and 4 P.M.

(3) It decreases rapidly from 4 P.M. to 7 P.M.

The following tables (VIII) and (IX) give the ratio of the actual air movement during each hour of the mean day in January and April to the mean hourly movement of these months. This eliminates to a large extent the differences of exposure of the instruments at the different stations, and shows the general character of the diurnal variation more clearly than the data of Tables VI and VII. The chief feature brought out by this mode of the presentation of the data is that the diurnal variation is more marked at the western than at the eastern stations in the Gangetic Plain.

TABLE VIII.—*Ratio of mean actual hourly air movement to mean hourly movement of the day in January.*

Hour.	Calcutta.	Hazaribagh.	Patna.	Lucknow.	Agra.	Roorkee.	Lahore.
0 to 1 . .	0·7	0·6	0·8	0·8	0·9	0·6	0·5
1 " 2 . .	0·7	0·6	0·8	0·8	0·9	0·7	0·5
2 " 3 . .	0·6	0·6	0·8	0·8	0·8	0·6	0·6
3 " 4 . .	0·6	0·6	1·0	0·9	0·9	0·7	0·6
4 " 5 . .	0·7	0·7	1·0	0·8	0·9	0·7	0·6
5 " 6 . .	0·7	0·7	1·0	0·8	0·9	0·7	0·6
6 " 7 . .	0·6	0·7	1·0	0·8	0·9	0·7	0·7
7 " 8 .	0·7	0·7	1·0	0·7	0·9	0·6	0·7
8 " 9 . .	1·0	1·0	0·9	0·8	0·9	0·7	1·6
9 " 10 . .	1·4	1·4	1·3	1·0	1·4	0·9	1·6
10 " 11 . .	1·6	1·7	1·4	1·3	1·4	1·4	1·7
11 " 12 . .	1·6	1·7	1·4	1·5	1·4	1·9	1·7
12 " 13 . .	1·7	1·7	1·2	1·8	1·7	2·3	2·1
13 " 14 . .	1·7	1·8	1·2	1·8	1·7	2·3	2·1
14 " 15 . .	1·6	1·7	1·3	1·7	1·7	2·1	2·1
15 " 16 . .	1·3	1·6	1·1	1·6	1·1	1·9	2·1
16 " 17 . .	1·1	1·5	1·1	1·1	1·1	1·2	0·6
17 " 18 . .	0·7	1·0	1·1	0·8	1·1	0·7	0·7
18 " 19 . .	0·6	0·8	0·8	0·8	0·8	0·6	0·7
19 " 20 . .	0·7	0·7	0·8	0·7	0·8	0·6	0·7
20 " 21 . .	0·8	0·6	0·8	0·8	0·8	0·6	0·4
21 " 22 . .	0·8	0·5	0·8	0·8	0·6	0·6	0·4
22 " 23 . .	0·8	0·5	0·8	0·8	0·6	0·7	0·4
23 " 0 . .	0·8	0·5	0·7	0·8	0·6	0·7	0·3

TABLE IX.—*Ratio of mean actual hourly air movement to mean hourly movement of the day in April*—concld.

Hour.	Calcutta.	Hazaribagh.	Patna.	Lucknow.	Agra.	Roorkee.	Lahore.
0 to 1 . .	0·8	0·7	0·7	0·7	0·6	0·5	0·8
1 " 2 . .	0·7	0·7	0·7	0·7	0·6	0·3	0·8
2 " 3 . .	0·7	0·7	0·7	0·7	0·6	0·3	0·8
3 " 4 . .	0·6	0·7	0·8	0·6	0·7	0·4	0·8
4 " 5 . .	0·6	0·7	0·8	0·6	0·7	0·3	0·7
5 " 6 . .	0·6	0·7	0·8	0·6	0·7	0·3	0·7
6 " 7 . .	0·7	0·8	1·1	0·7	0·8	0·3	0·7
7 " 8 . .	1·0	1·2	1·1	0·8	0·8	0·3	0·8
8 " 9 . .	1·1	1·2	1·1	1·0	0·8	0·7	1·4
9 " 10 . .	1·1	1·2	1·3	1·3	1·3	1·1	1·4
10 " 11 . .	1·2	1·3	1·3	1·4	1·3	1·6	1·4
11 " 12 . .	1·1	1·3	1·3	1·5	1·3	1·8	1·4
12 " 13 . .	1·2	1·5	1·3	1·5	1·7	1·9	1·6
13 " 14 . .	1·2	1·5	1·3	1·6	1·7	2·0	1·6
14 " 15 . .	1·2	1·6	1·4	1·7	1·7	2·1	1·6
15 " 16 . .	1·3	1·6	1·2	1·7	1·4	2·2	1·6
16 " 17 . .	1·3	1·4	1·2	1·5	1·4	2·1	0·8
17 " 18 . .	1·2	1·2	1·2	1·1	1·4	1·7	0·8
18 " 19 . .	1·2	0·7	0·8	0·8	0·8	1·1	0·8
19 " 20 . .	1·2	0·5	0·8	0·7	0·8	0·8	0·8
20 " 21 . .	1·1	0·6	0·8	0·7	0·8	0·7	0·8
21 " 22 . .	1·0	0·7	0·7	0·6	0·7	0·6	0·8
22 " 23 . .	0·9	0·7	0·7	0·6	0·7	0·5	0·8
23 " 0 . .	0·8	0·7	0·7	0·7	0·7	0·5	0·7

The ratios given in the two preceding tables (VIII and IX) indicate clearly that the mean diurnal variation of the air movement is as marked in the cold weather as in the hot weather season, and that it is somewhat more strongly pronounced at the western than the eastern stations of the Gangetic Plain.

The following table gives the mean air movement in 24 hours in January and April, and the ratio of the latter to the former for eight stations in Northern India :—

Station	Mean daily air movement in miles in		
	January (a)	April (b)	Ratio of b to a
Calcutta	68	175	2·6
Patna	48	108	2·3
Hazaribagh	118	201	1·7
Allahabad	50	86	1·7
Lucknow	57	106	1·9
Agra	82	114	1·4
Roorkee	52	76	1·5
Lahore	45	80	1·8

The preceding data establish that the ratios expressing the relative increase of the air movement from January to April are practically the same for stations in the Gangetic Plain (except Bihar) and Chota Nagpur, and average 1·7. The ratios are larger for Calcutta and Patna, thus indicating what is confirmed by an examination of the data of a large number of stations that the increase in the air movement is greatest in Bengal (averaging 3·0). The corresponding ratio for the Bihar stations is 2·4.

The following table gives the ratio of the maximum to the minimum velocity of the air movement during the mean days of the months of January and April for the eight stations of the preceding table :—

Station	Mean ratio of maximum to minimum air movement in miles in	
	January	April.
Calcutta	2·9	2·2
Patna	1·9	2·0
Hazaribagh	3·6	2·9
Allahabad	2·7	2·5
Lucknow	2·5	2·7
Agra	3·1	2·9
Roorkee	3·9	7·2
Lahore	7·5	2·3
Mean of all stations . .	3·4	3·1

The mean direction of the air movement (as determined from daily observations at 10 A.M. and 4 P.M.) is almost identical in every part of the Gangetic Plain in April

with that which obtains in January. The following gives data for a series of stations establishing this fact:—

TABLE X.

Station.	Mean wind direction. January. A.	Mean wind direction. April. B.	Difference in direction between January and April mean wind directions. B.—A.
Gaya	N 60° W	N 62° W	+2
Hazaribagh	N 62° W	N 74° W	+12
Patna	N 83° W	N 38° W	—45
Benares	N 78° W	N 80° W	+2
Allahabad	N 34° W	N 52° W	+18
Lucknow	N 57° W	N 53° W	—4
Agra	N 64° W	N 84° W	+20
Bareilly	N 55° W	N 57° W	+2
Delhi	N 77° W	N 65° W	—12
Meerut	N 49° W	N 53° W	+4
Roorkee	N 72° W	N 73° W	+1
Ludhiana	N 56° W	N 59° W	+3
Lahore	N 25° W	N 19° W	—6

Omitting Patna, the mean difference irrespective of sign is only 7°, and if sign be taken into account, it is only 4°. It is hence evident that the air movement in the Gangetic Plain is almost identical in direction in the month of April (representative of the hot weather) and the month of January (typical of the cold weather).

The preceding discussion hence establishes the following :—

First.—The air movement in the Gangetic Plain during the hot and cold weather months, and more especially from January to April or May, is unchanged in direction, and is an outflow from the interior of Northern India to the neighbouring seas, the direction of which is mainly determined by the lie of the river plain in which it occurs.

Second.—The air movement increases in intensity from January to April or May. The increase relatively to the actual movement in January is greatest in Bengal and Bihar (including the Sonthal Parganas).

Third.—The most important feature of the air movement is the diurnal variation which is however, relatively to the mean movement, probably not much more pronounced than at stations in the Peninsula or Central India. The diurnal variation of the air movement is even more marked in amount relative to the mean of the day in January than in April, but is less in absolute amount on the average in the cold than in the hot weather.

The following is a brief statement of the more important facts relating to the mean temperature and humidity conditions in Northern India, which it is desirable to bear in mind in considering any theory of the hot weather winds in the Gangetic Plain.

The temperature conditions are singularly regular in India. The absolute actual maximum temperature is usually recorded in the same area year after year, and usually ranges between 121° and 123° and is in three years out of four registered in the last week of May. The mean temperature data show even greater regularity. For example, the mean maximum temperature of the year occurs over the whole of Northern India on dates between the 21st May and the 3rd June (an interval of a fortnight), and the mean maximum temperatures in the North-Western Provinces and East Punjab range between 106° and 110°.

The maximum occurs on the mean of a large number of years on the same date in the North-Western Provinces and the South-East Punjab and a few days later than in Bihar.

The following table gives the highest mean maximum temperatures and the dates of their occurrence at a series of stations in Northern India:—

Station.	Highest mean maximum temperature.	Date of occurrence.
Hazaribagh	100·3°	21st May.
Patna	102·7	"
Gaya	106·5	"
Allahabad	107·3	4th June.
Lucknow	105·7	3rd "
Agra	109·5	" "
Roorkee	105·2	" "
Delhi	107·4	" "
Lahore	107·4	1st "

The preceding data, it may be noted, are based on the observations of 15 years, the means of which probably represent with approximate exactness the normal temperature conditions in Northern India. They show very clearly the small mean temperature differences which obtain over the whole of Northern India at the time of the greatest summer or tropical heat.

The mean temperature increases steadily from January to its maximum in May in the Gangetic Plain. The diurnal variation is similar in character, and the diurnal range practically the same in amount over the whole area. The following gives data of the diurnal range for six typical stations:—

Station	Mean Diurnal Range		Normal Average maximum or day temperature.		
	January.	April.	January.	April.	Total increase.
Patna	22·8°	27·6°	72·7°	100·9°	28·2°
Allahabad	26·3	31·9	74·0	104·0	30·0
Lucknow	27·4	31·3	73·8	102·3	28·5
Agra	25·0	29·3	73·5	102·8	29·3
Roorkee	25·2	31·5	69·5	98·1	28·6
Lahore	26·0	31·9	67·4	96·6	29·2

The preceding data establish—

(1) That the diurnal range is almost the same in mean amount over the whole of the Gangetic Plain in each of these two months. It averages 26° in January and 31° in April, when it has its maximum value.

(2) That the maximum or day temperature increases during the period from January to April by practically the same amount (*viz.*, 29°) over the whole area.

In Plate XXVII are given curves showing the diurnal variation of temperature in January and April at five of these stations for comparison. These curves show very clearly the similarity of the temperature conditions over the Gangetic Plain during the north-east or dry monsoon. They also indicate clearly that in the months of April and May, when the hot winds are most prevalent, the maximum temperature and the diurnal range of temperature are almost uniform in amount over the whole Gangetic Plain west of Central Bihar.

The amount of aqueous vapour present in the air increases slightly from January to April as is shown by the following data :—

Station.	Aqueous vapour pressure.		
	January.	April.	Percentage increase during period.
	"	"	
Patna	·371	·450	+21
Allahabad	·333	·358	+ 8
Lucknow	·297	·414	+39
Agra	·305	·367	+20
Roorkee	·295	·333	+13
Lahore	·262	·388	+48

The quantity of aqueous vapour is throughout the north-east or dry monsoon greater at the eastern than the western stations. It increases by nearly the same proportional amount at four of the six representative stations from January to April, but the increase is comparatively small, averaging barely 20 per cent. in amount. The aqueous vapour pressure has a well-marked diurnal oscillation at each of these stations, the character of which in the two seasons represented by the months of January and April will be seen by a reference to the curves given in Plate XXVIII.

A comparison of these curves establishes that the aqueous vapour pressure is subject to a double diurnal oscillation. The night oscillation is most marked in the cold weather and the day oscillation in the hot weather. This gives one of the more characteristic differences of the meteorology of the hot weather and cold weather periods. It should be carefully observed that the day oscillation in the hot weather is similar in general character in the two periods and only differs in its amplitude and period, indicating that the causes which produce this oscillation are most vigorous in the hot weather.

In the following table are given data of mean humidity, aqueous vapour pressure and weight of aqueous vapour per cubic foot for 10 A.M. and 4 P.M. of six representative stations in the Gangetic Plain and North-East Punjab, which will be useful for reference in the final discussion :—

Station.	Mean Humidity				Mean aqueous vapour pressure.				Grains of aqueous vapour per cubic foot.			
	April.		May.		April.		May.		April		May.	
	10 A.M.	4 P.M.	10 A.M.	4 P.M.	10 A.M.	4 P.M.	10 A.M.	4 P.M.	10 A.M.	4 P.M.	10 A.M.	4 P.M.
	%	%	%	%	"	"	"	"				
Patna	37	26	51	38	·516	·450	·726	·664	5·37	4·61	7·55	6·83
Allahabad	27	19	36	26	·407	·352	·603	·521	4·22	3·59	6·21	5·30
Lucknow	30	22	41	30	·433	·414	·613	·542	4·49	4·25	6·34	5·55
Agra	24	18	30	22	·362	·324	·487	·435	3·75	3·32	5·02	4·43
Roorkee	28	20	35	27	·364	·307	·483	·428	3·81	3·17	5·03	4·41
Lahore	32	22	31	25	·369	·315	·454	·415	3·87	3·26	4·70	4·25

The preceding data establish that the air is much drier at 4 P.M. than at 10 A.M. This is, however, chiefly a temperature effect. The vapour pressure data indicate that it is, however, in part due to an actual reduction in the weight per cubic foot of vapour present in the air, averaging about 12 per cent. of the mean total amount between 10 A.M. and 4 P.M. This decrease can be in part explained by the large easterly movement of the air between these hours bringing air from slightly drier to slightly damper districts. It is probable that the residual decrease to be explained by other actions, as for instance downrush of air accompanying upward convective movements, is small in amount and probably less than 6 per cent. of the mean total amount.

The preceding statements and discussion have shown the mean or normal features of the air movement in the Gangetic Plain during the hot weather. They, however, give a very inadequate idea of the characteristic features of the hot winds. This is due to the fact that the mean data are the averages of different types of weather. It is hence necessary to select for examination days on which the hot winds were most prominent, if we wish to arrive at their characteristic features.

An examination of the daily weather charts of the hot weather months of April and May shows that the actual pressure distribution in Northern India from day to day belongs, with few exceptions, to three different types during the hot season.

In the first type pressure is slightly lower in Chota Nagpur than elsewhere. Light unsteady or easterly winds obtain in the central and eastern districts of the Gangetic Plain and moderate southerly winds with much easting in Bengal. Thunderstorms and nor' westers are of frequent occurrence in Bengal during this distribution of pressure.

In the second type a low pressure area forms in Upper Sind and the South-West Punjab, usually during periods of excessive temperature. Such low pressure areas frequently move eastwards and give slightly disturbed weather in Upper India, dust storms occurring in the plains and thunderstorms in and near the hills. In a considerable number of cases they fill up for short periods, and reappear as stationary depres-

sions. Light, unsteady winds obtain in the Gangetic Plain during the prevalence of this distribution of pressure.

In the third type, which frequently follows the filling up of depressions in Upper India, low pressure areas form at the foot of the Nepal and Sikkim hills. When this type of distribution prevails, strong hot winds invariably blow down the Gangetic Plain. An examination of the charts for the past three years indicates clearly that vigorous hot winds as a rule only occur during this type of distribution of pressure in Northern India. In other words, they are only a normal feature of the period in so far that they are of occasional occurrence during the prevalence of peculiar pressure conditions, more especially of those of the type described above.

The following is a statement of the number of days in April and May 1893, 1894 and 1895 in which the pressure distribution belonged to these three different types of pressure:—

Month.	Number of days in month when the distribution of pressure in Northern India was of the			
	First type.	Second type.	Third type.	Other types.
April 1893	10	13	3	4
May 1893	8	12	1	10
April 1894	12	12	4	2
May 1894	7	7	11	6
April 1895	4	17	3	6
May 1895	7	14	6	4
Total	49	67	27	41
Percentage occurrence	27	36	15	22

The preceding data show that the third type of pressure distribution was unusually frequent in May 1894. The periods in that month, when it was most strongly exhibited, were the 14th to the 17th and the 25th to the 28th. The data illustrative of the special or most characteristic features of the hot winds will hence be obtained from these periods, and it will be sufficient to give anemometric data of three days, *viz.*, the 17th, the 26th and 27th, for stations in the Gangetic Plain in order to show the more striking features of the hot winds. Charts for the 17th and 27th, exhibiting the distribution of pressure and the direction of the air movement in Northern India at 8 A.M. on these days, are given in Plate XXIX.

The following tables give the actual air movement during each hourly interval of the day for the 17th, 26th and 27th May for the five stations, Calcutta, Allahabad, Roorkee,

Lahore and Darjeeling, which are provided with self-registering Beckley's anemographs (all of the same pattern):—

TABLE XI.—*Actual air movement during hourly intervals of the day on*

Hourly interval.	17th May 1894.					26th May 1894.					27th May 1894.				
	Allahabad.	Roorkee.	Lahore.	Calcutta.	Darjeeling.	Allahabad.	Roorkee.	Lahore.	Calcutta.	Darjeeling.	Allahabad.	Roorkee.	Lahore.	Calcutta.	Darjeeling.
Mid. to 1	6	6	7	9	12	7	10	2	18	23	13	5	7	14	5
1 „ 2	9	5	6	9	15	11	8	3	11	22	11	5	5	13	4
2 „ 3	6	5	3	7	12	10	5	3	16	23	10	7	2	17	6
3 „ 4	5	6	3	8½	10	11	6	4	14	13	8	7	3	14	10
4 „ 5	12	6	4	8	8	11	6	3	16	9	9	8½	2	14	10
5 „ 6	12	6	3	7	3	10	6	1	14	8	11	5	3	14	4
6 „ 7	11	0	3	7	1	13	8	0	21	3	9	5	2	16	1
7 „ 8	16	0	4	9	1	13	5	2	15	3	18	5	6	16	1
8 „ 9	25	6	3	10	1	24	8	2	12	1	25	4½	8	16	4
9 „ 10	29	7	3	11	2	26	13	6	15	1	35	6	11	15	[illegible]
10 „ 11	31	7	4	8	9	27	16	6	13	1	32	9	9	17	3
11 to Noon	30	8	4	9	4	27	20	8	13	1	30	9	9	14	7
Noon to 13	29	8	3	9	1	26	19	11	16	8	27	11	7	19	9
13 „ 14	34	9	6	7	0	33	20	9	14	9	24	9	6	17	20
14 „ 15	29	8	3	9	0	27	20	12	15	15	26	11	4	13	31
15 „ 16	31	8	5	8	1	26	17	14	12	28	25	15	6	22	30
16 „ 17	27	10	4	8	1	24	17	13	16	30	26	17	5	17	34
17 „ 18	26	8	8	11	0	19	16	4	13	20	21	16	2	14	41
18 „ 19	18	6	3	11	2	8	8	6	16	20	12	13	3	19	25
19 „ 20	11	5	12	8	5	3	7	7	13	11	8	10	4	18	18
20 „ 21	6	5	7	11	4	6	5	4	17	11	7	13	2	14	9
21 „ 22	5	5	6	11	5	6	5	5	13	16	6	13	4	12	3
22 „ 23	7	4	3	7	5	8	5	6	12	17	8	12	3	20	2
23 to Mid.	9	5	6	10	10	10	5	5	18	10	8	7	3	20	2

In the following are given the ratios of the maximum to the minimum velocity on the 17th, 26th and 27th May for four of these five stations:—

Station.	Date.	Hourly Velocity.			Normal ratio of maximum to minimum velocity of the air movement during the day in May.
		Maximum.	Minimum.	Ratio of maximum to minimum velocity.	
Allahabad	17th	34	5	6·8	2·5
	26th	33	3	11·0	
	27th	35	6	5·8	

Station.	Date.	Hourly Velocity. Maximum.	Minimum.	Ratio of maximum to minimum velocity.	Normal ratio of maximum to minimum velocity of the air movement during the day in May.
Calcutta	17th	11	7	1·6	2·2
	26th	21	10	2·1	
	27th	22	12	1·8	
Roorkee	17th	10	1	10·0	4·2
	26th	20	5	4·0	
	27th	17	4·5	3·8	
Lahore	17th	12	3	4·0	2·0
	26th	14	1	14·0	
	27th	11	2	5·5	

The comparison establishes that the ratio of the maximum to the minimum of the air movement on these dates was from two to seven times as large as the normal. This was chiefly due to the great intensity of the winds during the day hours.

The most noteworthy feature of the hot winds of the 17th, 26th and 27th May (and one which is very characteristic of the hot winds in their typical form) was the rapidity with which the winds increased between 8 and 10 A.M. and decreased between 5 and 7 P.M. at the stations in the Gangetic Plain. In contrast with this was the great steadiness in the strength of the winds at Calcutta. The changes in the force of the winds at Darjeeling are even more remarkable than at stations in the Gangetic Plain, but their full discussion is reserved for a future paper.

Another remarkable feature was that the minimum movement (occurring in the evening about 8 P.M.) was even less in amount than the normal or average at that hour.

Assuming that the data given above are fairly representative of the strength and intensity of the hot winds in Northern India in their typical form, it is evident that the hot winds proper blow with the force of a gale in the eastern and central districts of the North-Western Provinces from about 10 A.M. to 4 or 5 P.M., and decrease very rapidly until 7 or 8 P.M., when the air movement is so feeble as to be most suitably described by stating that the wind falls almost to a calm for a short period, and increases very slightly during the remainder of the night and again falls almost to a calm about sunrise.

The following gives temperature data of seven stations for the 17th, 26th and 27th May 1894, for comparison with the mean data in the second table, page 174:—

Station.	May 1894.								
	17th.			26th.			27th.		
	Maximum.	Minimum.	Range	Maximum.	Minimum.	Range	Maximum.	Minimum.	Range.
	°	°	°	°	°	°	°	°	°
Calcutta	103·4	81·7	21·7	94·1	83·2	10·9	95·6	83·7	11·9
Patna	108·5	81·7	26·8	112·6	87·1	25·5	114·1	83·2	30·9
Allahabad	108·6	81·3	27·3	113·7	85·2	28·5	113·1	87·7	25·4
Lucknow	106·3	82·1	24·2	111·8	85·1	26·7	113·3	84·1	29·2
Agra	107·5	82·7	24·8	114·0	81·7	32·3	114·5	82·7	31·8
Roorkee	102·7	79·9	22·8	108·2	79·9	28·3	109·7	77·0	32·7
Lahore	99·8	79·1	20·7	109·3	76·1	33·2	108·3	73·1	35·2

The preceding data establish that on these dates the hottest area was between Allahabad and Patna, and that the diurnal range was slightly above its normal amount. The maximum day temperatures were considerably in excess, and ranged between 110° and 114° over nearly the whole of the Gangetic Plain on the 26th and 27th. The maximum temperature on the 27th was 14°·5 above the normal at Patna, 6°·9 at Allahabad, 9°·6 at Lucknow and 7°·6 at Roorkee.

The temperature conditions were hence very pronounced on the 26th and 27th May 1894.

The following gives 10 and 16 hours humidity and aqueous vapour pressure data of these dates for the same stations:—

TABLE XII.

Station.	Aqueous vapour pressure.					
	17th		26th.		27th.	
	10 A.M.	4 P.M.	10 A.M.	4 P.M.	10 A.M.	4 P.M.
	"	"	"	"	"	"
Calcutta	·960	·477	1·030	·989	1·001	1·003
Patna	·659	·477	·366	·235	·836	·483
Allahabad	·433	·359	·291	·485	·336	·421
Lucknow	·603	·330	·229	·188	·222	·186
Agra	·496	·406	·282	·293	·392	·321
Roorkee	·610	·420	·208	·165	·206	·118
Lahore	·578	·551	·311	·257	·382	·272

TABLE XIII.

Station	Humidity. 17th. 10 A.M.	17th. 4 P.M.	26th. 10 A.M.	26th. 4 P.M.	27th. 10 A.M.	27th. 4 P.M.
	%	%	%	%	%	%
Calcutta	62	21	70	61	70	64
Patna	36	21	16	8	46	18
Allahabad	21	15	14	18	14	15
Lucknow	19	14	9	7	10	7
Agra	25	18	13	10	17	11
Roorkee	36	19	9	6	10	5
Lahore	35	26	16	11	20	11

The preceding data are very interesting. Those of Table XIII indicate the very low humidity which obtains at all stations in the Gangetic Plain during the prevalence of these hot winds, more especially in the afternoon hours.

The data of Table XII show that it is not possible to formulate any general relation with respect to the changes of the amount of aqueous vapour present in the air, without taking into account local conditions. It may be pointed out that they indicate the occurrence of large and (apparently) very irregular changes at the same station, and also from one station to another. Thus at Calcutta the aqueous vapour pressure on the 17th May fell from ·960″ at 10 A.M. to ·477″ at 4 P.M., a change accompanying a shift of wind from S. W. to W.S.W. This, it may be noted, is the largest change shown in this table. On the 26th and 27th the aqueous vapour pressure was almost constant at Calcutta. At Patna it fell considerably between 10 A.M. and 4 P.M. on the 17th and 26th, and very largely on the 27th from ·836″ at 10 A.M. to ·483″ at 4 P.M.—a change accompanying a shift of wind from an easterly to a westerly direction. At Roorkee, Lucknow and Lahore, the stations nearest to the Himalayas, the aqueous vapour pressure on each of these dates was less to a moderate extent at 4 P.M. than at 10 A.M., and this probably is an almost invariable rule at these stations. But at Allahabad it was higher on two of these days at 4 P.M. than at 10 A.M. and at Agra on one day.

The day variations in the amount of aqueous vapour during the prevalence of the hot winds are hence, at first sight, very irregular, and it is evident that they cannot depend upon any common or general action, such as descent of a mass of air from a higher to a lower level, but must depend largely, if not almost entirely, in the interior, upon local conditions (and perhaps proximity to the Himalayas), and near the coast upon the alterations of air currents of land and sea origin.

We have now shown to what extent the hot winds proper differ from the mean winds of the period. The chief difference lies in the great contrast between the day winds and the night airs. The temperature and humidity conditions do not differ from the normal to any

large extent. Both the day and night temperatures are higher, the day slightly more than the night temperature, so that the diurnal range is slightly increased. The air is even drier than usual, more especially in the day hours, when temperature is most largely in excess. But over the greater part of the area the mean aqueous vapour pressure differs little from the normal.

In order to investigate the origin of these hot winds which present so marked a diurnal periodicity, it is necessary to ascertain the varying pressure and temperature conditions and gradients that prevail during the day over the Gangetic Plain. The hourly observations for certain stations which have been discussed (*vide* Vol. V, Indian Meteorological Memoirs) enable this to be done. Tables will be found in each of these memoirs giving the pressure and temperature at each hour (local time) of the mean day of each month. From these, by the use of the ordinary interpolation formula to three terms, the pressure and temperature at the instants of local time corresponding to the hours of Calcutta time have been calculated, and are given in the following tables.

They hence give the pressure at the same absolute instants of time at hourly intervals throughout the mean day of January and of April, and thus enable an exact comparison to be made.

In the following tables the mean pressure at the same instants during the day are given for the seven stations of Calcutta, Patna, Allahabad, Lucknow, Agra, Roorkee and Lahore.

TABLE XIV.—*Mean pressure reduced to sea level and gravity at Lat. 45° at seven stations at each hour (Calcutta time) of the mean day in January.*

Hour. (Mean Calcutta time).	Calcutta.	Patna.	Allahabad	Lucknow.	Agra.	Roorkee.	Lahore.
	"	"	"	"	"	"	"
Midnight.	29·979	3·037	30·018	30·027	30·046	30·051	30·062
1	·972	·027	·011	·021	·038	·038	·060
2	·964	·017	006	·014	·028	·034	·058
3	·956	·008	29·999	·007	·022	·027	·053
4	·952	·005	·995	·001	·017	·025	·048
5	·960	·008	·996	·000	·017	·025	·045
6	·976	·020	30·005	·009	·025	·029	·044
7	·997	·043	·024	·025	·041	·040	·049
8	30·026	·069	·049	·048	·065	·058	·063
9	·050	·088	·071	·071	·088	·079	·079
10	·056	·093	·079	·081	·101	·088	·088
11	·038	·078	·070	·076	·095	·078	·089
Noon.	·009	·050	·045	·054	·076	·056	·076
13	29·975	·017	·012	·024	·044	·024	·053
14	·948	29·989	29·981	29·994	·011	29·994	·028

TABLE XIV.—*Mean pressure reduced to sea level and gravity at Lat. 45° at seven stations at each hour (Calcutta time) of the mean day in January*—concld.

Hour. (Mean Calcutta time.)	Calcutta.	Patna.	Allahabad.	Lucknow.	Agra.	Roorkee.	Lahore.
	"	"	"	"	"	"	"
15	29·931	29·972	29·964	29·970	29·989	29·973	30·006
16	·924	·965	·956	·960	·978	·964	29·995
17	·929	·968	·959	·962	·977	·969	·994
18	·938	·977	·969	·973	·986	·979	30·001
19	·954	·994	·985	·989	30·001	·994	·014
20	·972	30·014	30·000	30·007	·019	30·014	·029
21	·984	·031	·013	·021	·038	·031	·046
22	·990	·043	·020	·030	·047	·046	·053
23	·985	·043	·021	·032	050	·053	·061

TABLE XV.—*Mean pressure reduced to sea level and gravity at Lat. 45° at seven stations at each hour (Calcutta time) of the mean day in April.*

Hour. (Mean Calcutta time.)	Calcutta.	Patna.	Allahabad.	Lucknow.	Agra.	Roorkee.	Lahore.
	"	"	"	"	"	"	"
Midnight.	29·728	29·703	29·687	29·695	29·704	29·722	29·718
1	·717	·694	·679	·688	·695	·714	·717
2	·705	·681.	·669	·679	·685	·704	·710
3	·697	·675	·664	·672	·680	·695	·706
4	·698	·678	·665	·671	·683	·695	·703
5	·713	·692	·678	·679	·692	·708	·702
6	·731	·711	·697	·693	·711	·724	·713
7	·752	·731	·719	·711	·729	·742	·725
8	·774	·747	·737	·727	·748	·752	·738
9	·788	·757	·750	·740	·761	·758	·746
10	·789	·757	·752	·747	·764	·759	·761
11	·778	·746	·743	·742	·758	·754	·748
Noon.	·758	·727	·725	·728	·742	·741	·739
13	·729	·699	·697	·704	·720	·718	·724
14	·699	·668	·668	·677	·692	·692	·704
15	·672	·640	·640	·650	·664	·663	·681
16	·654	·621	·620	·632	·641	·640	·661
17	·650	·615	·612	·625	·628	·628	·648

TABLE XV.—*Mean pressure reduced to sea level and gravity at Lat. 45° at seven stations at each hour (Calcutta time) of the mean day in April*—concld.

Hour. (Mean Calcutta time.)	Calcutta.	Patna.	Allahabad.	Lucknow.	Agra.	Roorkee.	Lahore.
	"	"	"	"	"	"	"
18	29·661	29·622	29·616	29·629	29·629	29·630	29·647
19	·681	·638	·632	·642	·642	·645	·657
20	·704	·660	·652	·661	·663	·668	·675
21	·726	·682	·671	·680	·685	·692	·693
22	·736	·700	·686	·691	·701	·709	·707
23	·731	·707	·691	·697	·707	·720	·716

In the following are given the pressure differences between Allahabad and certain stations derived from the data of the preceding tables :—

TABLE XVI.—*Pressure differences between Allahabad and certain stations at each hour of the mean day of January.*

Hour. (Mean Calcutta time.)	Allahabad. minus Calcutta.	Allahabad. minus Patna.	Allahabad. minus Lucknow.	Allahabad. minus Agra.	Allahabad. minus Roorkee.	Allahabad. minus Lahore.
	"	"	"	"	"	"
Midnight	+·039	—·019	—·009	—·028	—·033	—·044
1	+·039	—·016	—·010	—·027	—·027	—·049
2	+·042	—·011	—·008	—·022	—·028	—·052
3	+·043	—·009	—·008	—·023	—·028	—·054
4	+·043	—·010	—·006	—·022	—·030	—·053
5	+·036	—·012	—·004	—·021	—·029	—·049
6	+·029	—·015	—·004	—·020	—·024	—·039
7	+·027	—·019	—·001	—·017	—·016	—·025
8	+·023	—·020	+·001	—·016	—·009	—·014
9	+·021	—·017	0	—·017	—·008	—·008
10	+·023	—·014	—·002	—·022	—·009	—·009
11	+·032	—·008	—·006	—·025	—·008	—·019
Noon	+·036	—·005	—·009	—·031	—·011	—·033
13	+·037	—·005	—·012	—·032	—·012	—·041
14	+·033	—·008	—·013	—·030	—·013	—·047
15	+·033	—·008	—·006	—·025	—·009	—·042
16	+·032	—·009	—·004	—·022	—·008	—·039
17	+·030	—·009	—·003	—·018	—·010	—·035

TABLE XVI.—*Pressure differences between Allahabad and certain stations at each hour of the mean day of January*—concld.

Hour. (Mean Calcutta time.)	Allahabad *minus* Calcutta.	Allahabad *minus* Patna.	Allahabad *minus* Lucknow.	Allahabad *minus* Agra.	Allahabad *minus* Roorkee.	Allahabad *minus* Lahore.
	"	"	"	"	"	"
18	+·031	—·008	—·004	—·017	—·010	—·032
19	+·031	—·009	—·004	—·016	—·009	—·029
20	+·028	—·014	—·007	—·019	—·014	—·029
21	+·029	—·018	—·008	—·025	—·018	—·033
22	+·030	—·023	—·010	—·027	—·026	—·033
23	+·036	—·022	—·011	—·029	—·032	—·040

TABLE XVII.—*Pressure differences between Allahabad and certain stations at each hour of the mean day of April.*

Hour. (Mean Calcutta time.)	Allahabad *minus* Calcutta.	Allahabad *minus* Patna.	Allahabad *minus* Lucknow.	Allahabad *minus* Agra.	Allahabad *minus* Roorkee.	Allahabad *minus* Lahore.
	"	"	"	"	"	"
Midnight	—·041	—·016	—·008	—·017	—·035	—·031
1	—·038	—·015	—·009	—·016	—·035	—·038
2	—·036	—·012	—·010	—·016	—·035	—·041
3	—·033	—·011	—·008	—·016	—·031	—·042
4	—·033	—·013	—·006	—·018	—·030	—·038
5	—·035	—·014	—·001	—·014	—·030	—·024
6	—·034	—·014	+·004	—·014	—·027	—·016
7	—·033	—·012	+·008	—·010	—·023	—·006
8	—·037	—·010	+·010	—·011	—·015	—·001
9	—·038	—·007	+·010	—·011	—·008	+·004
10	—·037	—·005	+·005	—·012	—·007	—·009
11	—·035	—·003	+·001	—·015	—·011	—·005
Noon	—·033	—·002	—·003	—·017	—·016	—·014
13	—·032	—·002	—·007	—·023	—·021	—·027
14	—·031	0	—·009	—·024	—·024	—·036
15	—·032	0	—·010	—·024	—·023	—·041
16	—·034	—·001	—·012	—·021	—·020	—·041
17	—·038	—·003	—·013	—·016	—·016	—·036
18	—·045	—·006	—·013	—·013	—·014	—·031
19	—·049	—·006	—·010	—·010	—·013	—·025
20	—·052	—·008	—·009	—·011	—·016	—·023
21	—·055	—·011	—·009	—·014	—·021	—·022
22	—·050	—·014	—·005	—·015	—·023	—·021
23	—·040	—·016	—·006	—·016	—·029	—·025

The data of Tables XVI and XVII establish that the pressure gradients in the Gangetic Plain during the cold and hot weather months vary considerably during the day in amount and have two maximum and two minimum values.

The following gives the maximum and minimum mean pressure differences during the day between Allahabad and Lucknow, Agra, Roorkee and Lahore, and their epochs for the month of January:—

Pair of Stations.	First maximum.	First minimum	Second maximum.	Second minimum
Lucknow *minus* Allahabad	+·011 11 P.M.	—·001 8 A.M.	+·013 2 P.M.	+·003 5 P.M.
Agra *minus* Allahabad	+·029 11 P.M.	+·016 8 A.M.	+·032 1 P.M.	+·016 7 P.M.
Roorkee *minus* Allahabad	+·033 Midnight	+·008 9 and 11 A.M.	+·013 2 P.M.	+·008 4 P.M.
Lahore *minus* Allahabad	+·054 3 A.M.	+·008 9 A.M.	+·047 2 P.M.	+·029 7 and 8 P.M.

The chief features indicated by the preceding figures are:—

1st.—The pressure gradients and differences vary considerably during the day.

2nd.—The absolute minimum gradients occur at 8 or 9 A.M. The differences are so small that pressure may be regarded as almost absolutely uniform over the Gangetic Plain at these hours. The mean pressure difference between Allahabad and Lahore at 8 A.M. is only ·008", between Allahabad and Lucknow only ·001" and between Lahore and Roorkee *nil*.

3rd.—The pressure differences increase rather rapidly from 10 A.M. until 2 P.M. when they are moderate in amount, averaging nearly ·05" in total amount between Lahore and Allahabad.

4th.—The gradients decrease from 3 P.M. to 7 or 8 P.M. when they are small in amount, but slightly greater than at 8 A.M. They increase from 8 P.M. to about midnight, when they are nearly as large as at 2 P.M.

5th.—The epoch of the early morning or night maximum is more variable than the epochs of the afternoon maximum and of the minimum values.

The following gives corresponding data for the month of April:—

Pair of stations	First maximum.	First minimum.	Second maximum.	Second minimum.
Lucknow *minus* Allahabad	+·010 2 A.M.	—·010 8 to 9 A.M.	+·013 5 to 6 P.M.	+·005 10 P.M.
Agra *minus* Allahabad	+·018 4 A.M.	+·010 7 A.M.	+·024 2 to 3 P.M.	+·010 7 P.M.
Roorkee *minus* Allahabad	+·035 Midnight to 2 A.M.	+·007 10 A.M.	+·024 2 P.M.	+·013 7 P.M.
Lahore *minus* Allahabad	+·042 3 A.M.	—·004 9 A.M.	+·041 3 to 4 P.M.	+·021 10 P.M.

The figures differ very slightly from those given for January, thus showing that

the mean gradients in their diurnal variation are practically the same in the two months in the Gangetic Plain. Hence during the whole period, from January to May, the pressure gradients in the Gangetic Plain have a strongly marked diurnal variation characterized by two maximum and minimum values. The chief features are —

1st.—Almost absolute uniformity of pressure in the Gangetic Plain from about 8 to 10 A.M.

2nd—Moderately steep gradients at about 2 P.M. and also in the early morning from about midnight to 2 A.M. The gradients are almost the same in amount at these two periods

3rd.—An afternoon minimum of gradients at about 7 P.M

In the two following tables are given corresponding data for temperature —

TABLE XVIII —*Mean temperature at seven stations at each hour (Calcutta time) of the mean day in January.*

Hour (Mean Calcutta time.)	Calcutta.	Patna.	Allahabad.	Lucknow	Agra.	Roorkee	Lahore.
Midnight	64°·1	56°·0	54°·6	52°·4	55°·7	50°·7	49°·1
1	63·4	54·7	53·3	50·9	54·3	49·3	47·9
2	62·8	53·9	52·6	50·0	53·2	48·3	47·1
3	62·2	53·2	52·3	49·6	52·7	47·4	46·9
4	61·6	52·2	51·8	49·1	52·2	46·5	46·8
5	61·1	50·9	50·7	48·2	50·8	45·6	46·2
6	60·6	50·1	49·5	46·9	49·1	44·6	45·1
7	60·3	50·9	49·6	46·7	48·3	44·1	44·3
8	62·5	53·8	51·9	48·6	49·5	45·0	44·9
9	66·0	58·4	56·2	53·0	53·2	48·0	47·7
10	69·3	63·0	61·3	58·8	58·4	53·1	52·3
11	72·1	66·7	66·0	64·1	63·3	58·8	57·1
Noon	74·4	69·1	69·6	68·0	67·0	63·4	61·2
13	75·8	70·7	72·3	70·4	69·6	66·3	64·2
14	76·8	71·7	74·0	72·2	71·6	67·9	66·2
15	77·1	72·1	74·6	73·6	73·0	68·8	67·4
16	75·7	71·3	73·4	73·8	73·4	68·6	67·3
17	74·2	69·2	70·4	72·0	72·1	66·7	65·7
18	71·6	66·2	66·2	68·2	68·9	63·6	62·3
19	69·6	63·3	62·1	63·5	65·0	60·3	58·2
20	68·1	61·1	59·3	59·4	61·6	57·7	54·5
21	66·9	59·8	57·9	56·6	59·5	55·9	52·2
22	65·9	58·7	57·1	55·1	58·2	54·2	50·9
23	65·1	57·5	56·1	53·9	57·1	52·4	50·1
Mean	67·8	60·6	60·1	58·5	59·9	55·3	54·0

TABLE XIX.—*Mean temperature at seven stations at each hour (Calcutta time) of the mean day in April.*

Hour. (Mean Calcutta time.)	Calcutta.	Patna.	Allahabad.	Lucknow.	Agra.	Roorkee.	Lahore.
	°	°	°	°	°	°	°
Midnight	80·1	80·1	79·9	77·9	82·1	74·6	75·0
1	79·7	78·8	78·6	77·0	80·9	72·6	74·0
2	79·3	77·5	77·5	76·2	79·8	71·5	73·1
3	79·0	76·1	76·3	75·2	78·7	70·8	72·1
4	78·6	74·8	74·7	73·7	77·2	69·5	70·9
5	78·3	73·9	73·3	72·4	75·5	66·7	69·6
6	78·1	74·1	73·3	72·5	74·6	64·9	68·9
7	79·0	76·5	75·7	75·0	75·7	66·8	69·6
8	81·8	80·5	80·7	79·9	79·1	72·2	72·4
9	84·8	85·3	87·1	85·7	84·2	79·0	76·9
10	87·4	89·5	93·0	90·9	89·6	84·5	82·2
11	89·8	92·8	97·1	94·3	93·8	88·1	86·7
Noon	91·5	94·9	99·3	96·4	96·5	90·6	89·8
13	92·7	97·0	100·7	98·0	98·1	92·6	91·7
14	93·4	98·0	101·9	99·6	99·5	94·2	92·8
15	93·4	98·9	102·9	100·8	100·5	95·2	93·7
16	92·5	98·6	102·5	100·7	100·9	95·4	93·9
17	90·5	97·0	100·3	98·7	99·8	94·3	93·0
18	87·7	93·9	96·4	95·1	97·3	91·8	90·6
19	85·2	90·7	92·0	91·0	94·0	87·6	87·1
20	83·3	87·7	87·8	87·1	90·4	83·3	83·4
21	82·1	85·2	85·6	84·0	87·5	80·2	80·2
22	81·3	83·2	83·0	81·4	85·4	78·4	77·9
23	80·6	81·5	81·3	79·4	83·6	76·7	76·3
Mean.	84·6	86·1	87·5	86·0	87·7	80·9	80·9

An examination of the tables shows that Allahabad and Patna are the hottest stations in the Gangetic Plain in April. In the following tables are given the actual temperature differences between Allahabad and the remaining stations, data for which are given in the preceding two tables, for each hour (Calcutta time) of the mean day in January and April :—

TABLE XX.—*Temperature differences between Allahabad and six other stations at each hour (Calcutta time) of the mean day in January.*

Hour. (Mean Calcutta time.)	Allahabad *minus* Calcutta.	Allahabad *minus* Patna.	Allahabad *minus* Lucknow.	Allahabad *minus* Agra.	Allahabad *minus* Roorkee.	Allahabad *minus* Lahore.
Midnight . .	° −9·5	° −1·4	° +2·2	° −1·1	° +3·9	° +5·5
1 . . .	−10·1	−1·4	+2·4	−1·0	+4·0	+5·4
2 . . .	−10·2	−1·3	+2·6	−0·6	+4·3	+5·5
3 . . .	−9·9	−0·9	+2·7	−0·4	+4·9	+5·4
4 . . .	−9·8	−0·4	+2·7	−0·4	+5·3	+5·0
5 . . .	−10·4	−0·2	+2·5	−0·1	+5·1	+4·5
6 . . .	−11·1	−0·6	+2·6	+0·4	+4·9	+4·4
7 . . .	−10·7	−1·3	+2·9	+1·3	+5·5	+5·3
8 . . .	−10·6	−1·9	+3·3	+2·4	+6·9	+7·0
9 . . .	−9·8	−2·2	+3·2	+3·0	+8·2	+8·5
10 . . .	−8·0	−1·7	+2·5	+2·9	+8·2	+9·0
11 . . .	−6·1	−0·7	+1·9	+2·7	+7·2	+8·9
Noon . . .	−4·8	+0·5	+1·6	+2·6	+6·2	+8·4
13 . . .	−3·5	+1·6	+1·9	+2·7	+6·0	+8·1
14 . . .	−2·8	+3·3	+1·8	+2·4	+6·1	+7·8
15 . . .	−2·5	+2·5	+1·0	+1·6	+5·8	+7·2
16 . . .	−2·3	+2·1	−0·4	0	+4·8	+6·1
17 . . .	−3·8	+1·2	−1·6	−1·7	+3·7	+4·7
18 . . .	−5·4	0	−2·0	−2·7	+2·6	+3·9
19 . . .	−7·5	−1·2	−1·4	−2·9	+1·8	+3·9
20 . . .	−8·8	−1·8	−0·1	−2·3	+1·6	+4·8
21 . . .	−9·0	−1·9	+1·3	−1·6	+2·0	+5·7
22 . . .	−8·3	−1·6	+2·0	−1·1	+2·9	+6·2
23 . . .	−9·0	−1·4	+2·2	−1·0	+3·7	+6·0

TABLE XXI.—*Temperature differences between Allahabad and six other stations at each hour (Calcutta time) of the mean day in April.*

Hour. (Mean Calcutta time.)	Allahabad *minus* Calcutta.	Allahabad *minus* Patna.	Allahabad *minus* Lucknow.	Allahabad *minus* Agra.	Allahabad *minus* Roorkee.	Allahabad *minus* Lahore.
Midnight	° −0·2	° −0·2	° +2·0	° −2·2	° +5·3	° +4·9
1	−1·1	−0·2	+1·6	−2·3	+6·0	+4·6
2	−1·8	0	+1·3	−2·3	+6·0	+4·4
3	−2·7	+0·2	+1·1	−2·4	+5·5	+4·2
4	−3·9	−0·1	+1·0	−2·5	+5·2	+3·8

TABLE XXI.—*Temperature differences between Allahabad and six other stations at each hour (Calcutta time) of the mean day in April*—concld.

Hour. (Mean Calcutta time.)	Allahabad *minus* Calcutta.	Allahabad *minus* Patna.	Allahabad *minus* Lucknow.	Allahabad *minus* Agra.	Allahabad *minus* Roorkee.	Allahabad *minus* Lahore.
	°	°	°	°	°	°
5	−5·0	−0·6	+0·9	−2·2	+6·6	+ 3·7
6	−4·8	−0·8	+0·8	−1·3	+8·4	+ 4·4
7	−3·3	−0·8	+0·7	0	+8·9	+ 6·1
8	−1·1	+0·2	+0·8	+1·6	+8·5	+ 8·3
9	+2·3	+1·8	+1·4	+2·9	+8·1	+10·2
10	+5·6	+3·5	+2·1	+3·4	+8·5	+10·8
11	+7·7	+4·3	+2·8	+3·3	+9·0	+10·4
Noon	+7·8	+4·4	+2·9	+2·8	+8·7	+ 9·5
13	+8·0	+3·7	+2·7	+2·6	+8·1	+ 9·0
14	+8·5	+3·9	+2·3	+2·4	+7·7	+ 9·1
15	+9·5	+4·0	+2·1	+2·4	+7·7	+ 9·2
16	+10·0	+3·9	+1·8	+1·6	+7·1	+ 8·6
17	+ 9·8	+3·3	+1·6	+0·5	+6·0	+ 7·3
18	+ 8·7	+2·5	+1·3	−0·9	+4·6	+ 5·8
19	+ 6·8	+1·3	+1·0	−2·0	+4·4	+ 4·9
20	+ 4·5	+0·1	+0·7	−2·6	+4·5	+ 4·4
21	+ 3·5	+0·4	+1·6	−1·9	+5·4	+ 5·4
22	+ 1·7	−0·2	+1·6	−2·4	+4·6	+ 5·1
23	+ 0·7	−0·2	+1·9	−2·3	+4·6	+ 5·0

The preceding data are very instructive, as they show that the temperature differences or gradients vary very considerably during the day, due mainly to the fact that the diurnal heating action of the sun commences considerably later at the western than at the eastern stations in the Gangetic Plain. The following states the more important features disclosed by the preceding tables:—

Temperature is highest in the cold weather in Bengal and diminishes westwards up the Gangetic Plain. The mean temperature gradients increase in amount from east to west over the Gangetic Plain. The temperature gradients, however, vary very considerably in amount during the day and have their absolute minimum values about 6 to 8 P.M., and their absolute maximum values from 8 to 10 A.M. Temperature at Lucknow and Agra relatively to Patna and Allahabad is higher in the night hours, or the temperature gradients are reversed in direction from 5 P.M. to 5 A.M., the differences being greatest from 6 P.M. to 7 P.M. The temperature of Lahore and Roorkee in January is throughout the whole 24 hours period below that of Allahabad and Patna. The differences are least in the evening from 6 to 8 P.M. and increase slightly during the night hours up to 6 A.M., and thence rapidly up to the maximum at 10 A.M. They thence decrease

lowly until 2 P.M. and afterwards rapidly to the minimum at 7 or 8 P.M.

The following table gives briefly the chief data showing the effect of the difference f longitude in modifying the temperature differences or gradients in the Gangetic Plain n January :—

Pair of stations.	Temperature differences.			
	Minimum. (a).	Maximum. (b).	Mean of day.	b—a.
	°	°	°	°
Allahabad *minus* Calcutta	—2·3	—11·1	—7·7	—8·8
Allahabad *minus* Roorkee	1·6	8·2	4·8	6·6
Allahabad *minus* Lahore	3·9	9·0	6·1	5·1
Patna *minus* Roorkee	2·5	10·4	5·3	7·9
Patna *minus* Lahore	3·5	10·7	6·6	7·2

In the hot weather (as represented by the month of April) the hottest area ı the Gangetic Plain includes Allahabad, Patna and Lucknow, the centre being llahabad. There are steep temperature gradients to the west of that area as far as the 'unjab and also to the south-east towards the Bay of Bengal.

The maximum temperature gradients in the western half of the Indo-Gangetic lain (*i.e.*, to the west of Allahabad) occur from 10 A.M. to 11 A.M. and the minimum om 7 P.M. to 8 P.M., or on the average an hour later than in the cold weather. The :mperature gradients to the south-east (as given by the temperature differences between llahabad and Calcutta) are greatest from 4 P.M. to 5 P.M., and hence late in the after- oon.

The following gives temperature data for the month of April, showing the effect of ıfference of longitude in varying the temperature gradients during the mean day of that ıonth in the Gangetic Plain :—

Pair of stations.	Temperature differences.			
	Minimum. (a).	Maximum. (b).	Mean of day.	b—a.
	°	°	°	°
Allahabad *minus* Calcutta	—5·0	10·0	2·9	15·0
Allahabad *minus* Lucknow	0·7	2·9	1·5	2·2
Allahabad *minus* Roorkee	4·4	9·0	6·6	4·6
Allahabad *minus* Lahore	3·7	10·8	6·6	7·1
Patna *minus* Calcutta	—4·4	6·5	1·5	10·9
Patna *minus* Lucknow	—2·1	2·2	0·1	4·3
Patna *minus* Roorkee	2·1	9·7	5·2	7·6
Patna *minus* Lahore	3·3	8·4	5·2	5·1

The diurnal variation of the temperature gradients is the same in general character April as in January, the chief difference being that gradients between Allahabad and

Calcutta are much steeper in April and are reversed in direction, a change which is accompanied by a great increase in the strength of the winds in South Bengal. The maximum and minimum gradients during the day between Allahabad and Upper India (represented by Roorkee and Lahore) are almost identical in amount in the two months thus showing that they are mainly determined by conditions dependent on difference of longitude and not of latitude. As already stated the actual temperature differences or gradients are feeblest in the afternoon shortly after sunset and increase very slightly during the night hours until 5 or 6 A.M. They then increase rapidly until 9 or 10 A.M., when the maximum gradients obtain. They decrease slowly until 3 P.M., and thence rapidly to the minimum of the day at 6 or 7 P.M.

Data have now been given showing all the more important features of the air movement and the accompanying temperature, pressure and humidity conditions in the Gangetic Plain during the period in which dry westerly winds of continental or land origin usually prevail, and also the pressure and other conditions accompanying the *development of these winds into the "violent day winds" of occasional occurrence in* the hot weather month, which alone are regarded by the inhabitants of Northern India as the "hot winds" of the Gangetic Plain.

It has been shown in page 169 that the most noteworthy feature of the air movement in Northern India during the dry or north-east monsoon is the diurnal variation *of the strength of the winds. The diurnal rotation of the wind direction in the case* of the stations of Allahabad, Lucknow, Agra, Roorkee and Lahore has been discussed in the memoirs on the hourly observations of these stations (*vide* Meteorological Memoirs, Vol. V). The diurnal rotation is fairly well marked, and its amount and character depend, to a considerable extent, upon the position of the stations relative to the Himalayas.

The following table gives the mean wind direction at six-hourly intervals during the mean day of the period from October to February and of the period from March to May, for the five stations in the Gangetic Plain named above, and hence shows the most prominent features in the diurnal shift of wind at these stations in these two periods:—

STATION	MEAN WIND DIRECTION							
	OCTOBER TO FEBRUARY				MARCH TO MAY			
	4 A.M.	10 A.M.	4 P.M.	10 P.M.	4 A.M.	10 A.M.	4 P.M.	10 P.M.
Allahabad . . .	N 51° W	N 87° W	N 26° W	N 45° W	N 15° W	N 3° W	N 31° W	N 51° E
Lucknow . .	N 41° W	N 32° W	N 35° W	N 45° W	N 39° W	N 41° W	N 47° W	N 44° W
Agra	N 80° W	S 89° W	N 62° W	?	N 79° W	S 88° W	N 78° W	?
Roorkee . . .	N 82° W	S 2° E	N 71° W	N 76° W	N 84° W	S 26° E	N 74° W	N 65° W
Lahore . .	N 30° E	N 5° W	N 50° W	N 5° E	N 16° E	N 20° E	N 28° W	N 30° E

It has also been shown that the intensified westerly winds of April and May, or the hot winds proper, do not differ in their general characteristics from the mean winds of the period. The contrast between the strength of the day and night winds is much greater, and the diurnal range of temperature and aqueous vapour pressure and the intensity of the heat during the day are greater during the prevalence of the true "hot winds" of the period. The following gives an illustration of the actual conditions from

the hourly observations recorded at Allahabad and Patna on the 7th May 1883 in illustration of these remarks :—

TABLE XXII.—*Results of hourly observations at Allahabad on the 7th May 1883.*

Hour	Temperature	Vapour	Humidity	Wind: Direction	Wind: Velocity	Weather *
	°	"	%			
Midnight	84·2	·345	30	Calm	Not available.	b
1	84·2	·348	30	Calm		b
2	83·4	·325	28	SW		b
3	86·7	·260	22	SW		b
4	86·8	·303	23	SW		b
5	83·5	·287	26	SW		b
6	80·0	·301	30	Calm		b
7	83·2	·368	32	Calm		b
8	91·7	·326	22	W		b
9	99·6	·325	17	NW		b
10	104·5	·279	13	NW		b hw
11	108·0	·301	12	NW		b hw
Noon	110·7	·329	13	NW		b hw
13	111·9	·313	12	NW		b hw
14	111·3	·289	11	W		b hw
15	111·9	·329	12	NW		b hw
16	110·0	·314	12	NW		b hw
17	108·1	·253	10	NW		b hw
18	103·5	·315	15	Calm		b
19	95·7	·420	25	Calm		b
20	92·5	·346	23	Calm		b
21	91·7	·303	20	Calm		b
22	87·7	·305	23	Calm		b
23	86·7	·281	23	Calm		b

TABLE XXIII.—*Results of hourly observations at Patna on the 7th May 1883*

Hour	Temperature	Vapour	Humidity	Wind: Direction	Wind: Velocity	Weather *
	°	"	%		Miles	
Midnight	82·2	·868	79	E	2	b
1	79·6	·833	82	E	5	b
2	79·3	·829	82	E	5	b
3	79·1	·823	82	E	5	b

* NOTE.—b in weather column signifies blue sky
hw ditto ditto hot wind.

TABLE XXIII.—*Results of hourly observations at Patna on the 7th May 1883*—concld.

Hour	Temperature.	Vapour	Humidity	Wind		Weather*
				Direction	Velocity	
	°	"	%		Miles.	
4	76·5	·824	91	ENE	6	c
5	75·5	·813	92	ENE	6	o
6	75·9	·824	92	ENE	6	o
7	77·5	·828	88	E	6	o
8	81·2	·829	78	E	6	c
9	86·0	·816	65	ENE	6	b
10	90·0	·775	48	SE	5	b
11	97·7	·588	33	NNW	5	b
Noon	103·7	·491	23	NW	5	b
13	106·7	·408	17	NW	8	b
14	108·3	·353	14	NW	8	b
15	108·9	·337	14	N	8	b
16	107·7	·345	15	NW	8	b
17	104·7	·377	17	NNW	8	b
18	101·7	·410	21	NW	8	b
19	96·7	·470	26	NW	2	b
20	93·3	·507	32	NW	2	b
21	91·4	·525	35	ENE	2	b
22	88·6	·579	43	ENE	2	b
23	87·4	·611	47	ENE	2	b

The daily weather charts show that the pressure conditions in Northern India on the 7th May 1883 were similar to those of May 26th and 27th, 1894, but were much less strongly marked.

The following relations between the maximum and minimum phases of the air movement and the other meteorological elements obtained from the previous discussion are important for testing any theory of the origin of the hot winds. The relations are chiefly derived from the mean data and hence apply most directly to the normal air movement of the period, but almost certainly apply equally to the exaggerated winds of the period known as the hot winds.

(1) The absolute minimum of the air motion in the north-east or dry monsoon, more especially in the hot weather, occurs at about 7 P.M. or 8 P.M., or slightly earlier than the epoch of the minimum temperature gradient of the day, and precedes that of the evening minimum pressure gradient in the Gangetic Plain by an average of about three hours.

(2) The absolute maximum of the air movement in the Gangetic Plain is practically coincident with the epoch of maximum temperature and precedes the day maxi-

* NOTE.—*b* in weather column signifies blue sky
c ditto ditto partial clouds
o ditto ditto overcast.

mum pressure gradient by an interval of at least one hour. The rapid increase of air movement during the day from 8 A.M. to 2 P.M. accompanies increasing pressure gradients and large temperature gradients.

(3) The period of most rapid increase of velocity (8 A.M. to 9 AM.) is practically simultaneous with the period of maximum temperature gradients, and of feeblest pressure gradients in the morning and the period of most rapid decrease of velocity (from 5 P.M. to 7 P.M.) with the period of rapid decrease of temperature gradients in the afternoon.

(4) There is a slightly marked tendency to increase of air movement during the night from about 10 P.M. to 2 A.M. and to slight decrease shortly before and after sunrise. The former is coincident with the night maximum gradient of pressure, and the latter precedes the morning minimum pressure gradient (at about 8 A.M. to 9 A.M.)

According to all meteorologists who have discussed the theory of hot winds, convection movements play an important part. Convection air movements are undoubtedly most vigorous in Northern India in the hot weather. The cause of these movements is not to be sought for in the actual temperature of the air, nor in the diurnal range of temperature, but in the excessive heating of the surface soil by the solar action in the hot weather months, and the consequent rapid decrease of temperature with elevation in the lowest air strata. It is not possible to give an exact measure of this convective action, but the ground temperature observations taken at Allahabad, Jeypore and Lahore furnish data which are of use.

In the following table are given the temperatures of the ground surface and the temperatures at 4 feet above the ground determined by observations of a thermometer in a thatched shed at 2 P. M. or 4 P. M. or about the hottest time of the day. It is almost certain that the mean temperature at 4 feet above the ground in the observatory sheds differs very slightly from the temperature at the same elevation above the ground in the open, and hence the recorded temperature data in the shed may be utilized for the temperature at 4 feet above the ground in the observatory compound immediately outside of the shed, where the ground surface temperature is measured. The table gives comparative data for the three stations in Northern India at which these observations are recorded :—

TABLE XXIV.—*Mean temperature of the ground surface and of the air at 4 feet above the ground, and their differences during the hottest part of the day.*

Station.	Month and year.	2 P.M.		
		Mean temperature, ground surface.	Mean temperature of air 4 ft. above ground	Difference between ground and air temperature.
Allahabad	January 1894	83°5	76°0	7°5
	February „	92·4	78·2	14·2
	March „	119·8	90·4	29·4
	April „	135·7	102·8	32·9
	May „	142·8	109·5	33·3
	June „	126·2	99·4	26·8
	July „	109·1	90·0	19·1

TABLE XXIV.—*Mean temperature of the ground surface and of the air at 4 feet above the ground and their differences during the hottest part of the day*—concld.

Station.	Month and year	4 P.M.		
		Mean temperature, ground surface	Mean temperature of air 4 ft. above ground.	Difference between ground and air temperature.
		°	°	°
Jeypore	January 1894	81·7	69·8	11·9
	February „	96·4	77·1	19·3
	March „	112·5	87·7	24·8
	April „	125·9	99·3	26·6
	May „	130·6	105·0	25·6
	June „	116·0	95·1	20·9
	July „	104·3	86·5	17·8
		°	°	°
Lahore	January 1894	58·0	60·0	–2·0
	February „	70·0	66·5	3·5
	March „	90·5	78·6	11·9
	April „	117·1	94·6	22·5
	May „	129·0	104·0	25·0
	June „	125·0	100·4	24·6
	July „	112·6	90·5	22·1

The data indicate that the differences are small to moderate in amount in the cold weather months and increase rapidly from February until May. Thus at Allahabad the mean difference between the air and ground temperature at 2 P. M. in January 1894 was 7°·5 and in May 33°·3. Hence the differences of temperature in the lowest stratum of air near the earth's surface and which give rise to convective currents are nearly five times as great in May as in January at Allahabad.

The Lahore observations indicate that the contrast between the vertical temperature gradients near the earth's surface in the months of January and May, becomes more marked as we advance westwards up the Gangetic Plain, due, however, not to increased gradients in the hot weather, but to decreased gradients in the cold weather. At Lahore, and probably in the Punjab generally, the ground is throughout the whole day cooler than the adjacent air.

The preceding discussion has shown as fully as can be done from the available normal data the characteristic features of the hot winds of Northern India and the accompanying meteorological conditions.

It has been established that the hot winds proper are an abnormal development of the westerly winds of the Gangetic Plain under special pressure conditions. The actual pressure conditions, including the variations of the gradients during the day, have not yet been fully ascertained. I propose shortly to call upon certain stations to record

hourly observations on the days when these winds are most vigorous, and thus accumulate the further data necessary for their full explanation. This will probably require some time, and the present discussion is hence preliminary to the future discussion that will be made when sufficient special observations of these winds and the accompanying pressure, temperature, and humidity conditions have been accumulated. In the present paper it is only possible to investigate the conditions and phenomena of these winds fully so far as they can be traced from mean data.

The westerly winds in the Gangetic Plain are common to the whole period from November to May. The direction of the air movement during the period shows that it is parallel to the lie of the isobars and also to that of the axis of the plain itself. Also, during the whole of the period the strength of the air current blowing down the Gangetic Plain appears to have little or no direct connection with the very feeble gradients or differences of pressure down the plain. As Hill points out justly, the strength of the mean movement down the Gangetic Plain increases from January to May, during which period the mean gradients in the direction of the Gangetic Plain are very small, and also on the whole decrease, rather than increase, in amount with the progress of the season. On the other hand, as Hill also remarks, temperature increases *pari passu* with the increasing air movement, and hence the velocity of the air movement in the horizontal direction appears to be directly related to the temperature of the air stratum nearest to the earth's surface. Considering the mean wind data given by the hourly observations of Hazaribagh, Patna, Lucknow, Agra, Roorkee and Lahore for the month of April, we have the following as the more prominent features of the winds of the period (and hence of the ordinary hot winds):—

(1) The air movement in its diurnal variation is nearly constant from 7 P.M. to 8 A.M., and is feeble.

(2) There is a slight increase from a minimum at about 7 P.M. to a very feeble maximum between 10 P.M. and midnight, and afterwards a slight decrease to a morning minimum from about 6 A.M. to 8 A.M.

(3) The air movement increases from 8 A.M. to 2-30 P.M. and decreases from 2-30 P.M. to 7 P.M., and the amplitude of this oscillation relatively to the mean air movement is large and strongly pronounced.

(4) The increase of the air movement occurs chiefly during the interval from 8 A.M. to noon and the decrease from 4 P.M. to 7 P.M. The rate of decrease is hence somewhat larger than that of increase. The former is a maximum from 8 to 9 A.M., and the latter from 5 P.M. to 7 P.M. The mean maximum air movement at 2-30 P.M. is three times as great as the mean minimum at 7 P.M. or 8 A.M.

(5) The mean air movement and the amplitude of the diurnal variation increase from west to east as far as the eastern districts of the North-Western Provinces and (probably) South Bihar.

The consideration of the data of the strong hot winds of May 1894 (given in page 178) shows that the chief features of the diurnal variation of the strongest hot winds in

the Gangetic Plain are the same in general character as those of the mean winds of the months of April and May. The absolute maximum air movement occurs at about 2-30 P.M. on the average and the absolute minimum from 8 to 10 P.M. The velocity increases slightly and irregularly during the next three or four hours, and thence falls again to a secondary minimum occurring between 5 and 8 A.M. The contrast between the feeble night winds and the strong winds in the middle of the day is very marked and is much greater than in the mean winds of the period. Curves representing the diurnal variation of the mean air movement in January and April for stations in Northern India are given in Plate XXVI. Also, curves exhibiting the mean diurnal variation of the air movement of the selected days in May 1894, representative of the strongest hot winds, are given in Plate XXX for three plains stations in Northern India and the corresponding air movement at Darjeeling. The comparison of these curves with the curves of the mean air movement in April, which are also given in Plate XXX, is very instructive.

The chief points which require explanation in the mean winds of April and May and the strong hot winds of the same period are hence—

1st.—The large day oscillation from 8 A.M. to 7 P.M.

2nd.—The feeble night oscillation.

The feeble night oscillation, it may again be noted, although very slight, is a regular feature of the mean air movement of the period, and is very marked in the strongest hot winds, as may be seen from the curves of Plate XXX (figures 1 to 4).

We have in the first place to correlate the diurnal variation of the mean winds in the hot weather with the corresponding variations of the meteorological elements of pressure or of temperature, and then to ascertain, so far as possible, the causes or nature of these relations.

The diurnal variation of the pressure gradients in the direction of the axis of the Gangetic Plain is well marked. In Plate XXXI are plotted curves representing the diurnal variation of gradients for the months of January and April as shown—

(1st) by the pressure differences between Allahabad and Lucknow,

(2nd) by the pressure differences between Allahabad and Roorkee,.

(3rd) by the pressure differences between Roorkee and Lahore, and

(4th) by the pressure differences between Allahabad and Lahore,

and in Plate XXXII are given the mean hourly actual pressure gradients between Allahabad and Lucknow, Allahabad and Roorkee, Roorkee and Lahore, and Allahabad and Lahore for the mean days of January and April. A reference to the data given in Tables XVI and XVII, or to the curves in Plates XXXI and XXXII shows clearly that the diurnal variation of gradient has a double oscillation in each month, and that the maximum values in April occur at about 3 A.M. and 4 P.M. (absolute Calcutta time), and the minimum values at 9 A.M. and from 7 P.M. to 10 P.M.

The morning minimum is strongly marked, and the mean pressure gradient between Lahore and Allahabad at that time (9 A.M.) is nearly evanescent. The following gives the mean maximum and minimum gradients down the Gangetic Plain and the hours

of their occurrence, as determined from the pressure differences of Allahabad and Lahore:—

January.

Phase.	Hour.	Lahore *minus* Allahabad.	
		Total pressure difference or gradient.	Mean gradient, assuming as unit ·01 inch per 15 geographical miles.
Morning maximum	3 A.M.	·054	·13
Do. minimum	9 A.M.	·008	·02
Afternoon maximum	2 P.M.	·047	·11
Evening minimum	8 P.M.	·029	·07
April.			
Early morning maximum	3 A.M.	·042	·10
Morning minimum	9 A.M.	—·004	—·01
Afternoon maximum	4 P.M.	·041	·10
Evening minimum	10 P.M.	·021	·05

A comparison of these figures with the mean wind data shows—

1st.—Winds in their diurnal variation increase most rapidly from 7 A.M. to 9 A.M., and hence at the time when the mean gradients between Lahore and Allahabad are smallest in amount and in fact almost *nil.*

2nd.—Gradients are steepest during the mean day of April at about 4 P.M., *i.e.*, about two hours after the winds are strongest and immediately antecedent to their period of most rapid decrease from 4 P.M. to 6 or 7 P.M.

3rd.—The gradients are as steep at 3 A.M., when winds are very light, as they are at 4 P.M., shortly after the day maximum of the air movement.

The preceding data hence indicate that the diurnal variation of the pressure gradients and the horizontal air movement in the Gangetic Plain during the dry monsoon are not directly related as cause and effect, although the gradients undoubtedly contribute to some extent to the movement.

We have next to consider the relations between the diurnal variation of the temperature conditions and the intensity of the hot winds of Northern India in April and May. Air motion, as dependent upon temperature, is, it may be premised, not a function of temperature, but of temperature differences in their relation to space or time. It has been shown *(in page 174) that the mean or maximum* temperatures during the months of April and May and the diurnal ranges of temperature are almost identical in amount over the whole of the Gangetic Plain, *i.e.*, the area in which the hot winds under discussion obtain. The mean temperature conditions in the Gangetic Plain are hence not directly related to the intensity of these winds. It has, however, been shown (*vide* Table XXI) that, although the differences of the mean temperature of the day or of the

temperature at a given hour, local time, at stations in the plains of Northern India are small in amount, the actual differences at the same absolute instants during the day vary very considerably; and that the horizontal temperature gradients are large in amount during the morning hours from 7 or 8 A.M. to 2 or 3 P.M.

The actual or absolute temperature gradients in the months of January and April are indicated by the data of Tables XX and XXI (*vide* pages 189-190) and are for easy reference charted in Plates XXXIII and XXXIV in two forms: 1st, as actual differences, and 2nd, as rates of increase or decrease with distance expressed in terms of a unit of rise of one degree per 100 geographical miles.

The following gives the maximum and minimum temperature differences between Allahabad and four stations in the North-Western Provinces and East Punjab during the mean day of April and their epochs (mean Calcutta time):—

Phase.	Allahabad *minus* Lucknow.		Allahabad *minus* Agra.		Allahabad *minus* Roorkee.		Allahabad *minus* Lahore.	
	°	Epoch.	°	Epoch.	°	Epoch.	°	Epoch.
Morning minimum	+0·7	7 A.M.	−2·5	A.M.	+5·2	4 A.M.	+ 3·7	5 A.M.
Do. maximum	+2·9	Noon	+3·4	10 A.M.	+9·0	11 A.M.	+10·8	10 A.M.
Evening minimum	+0·7	8 P.M.	−2·6	8 P.M.	+4·4	7 P.M.	+ 4·4	8 P.M.
Night maximum	+2·0	Midnight	−1·9	9 P.M.	+6·0	2 A.M.	+ 5·4	9 P.M.

The absolute maximum temperature differences in the Gangetic Plain are at 11 A.M and the absolute minimum at 8 P.M. The secondary maximum differences are at about 9 P.M. and the secondary minimum at about 5 A.M.

The following gives the maximum and minimum temperature gradients per hundred miles of distance during the mean day of April for the five pairs of stations:—

Phase.	Mean temperature gradient (1° per 100 Geographical miles).									
	Lucknow to Allahabad.		Roorkee to Lucknow.		Roorkee to Allahabad.		Roorkee to Lahore.		Lahore to Allahabad.	
	°	Epoch.	°	Epoch	°	Epoch.	°	Epoch.	°	Epoch.
Morning minimum	+0·6	7 A.M.	+1·6	4 A.M.	+1·4	4 A.M.	−1·7	6 A.M.	+0·6	5 A.M.
Do. maximum	+2·5	Noon	+3·1	7 A.M.	+2·4	11 A.M.	+1·0	10 A.M.	+1·8	10 A.M.
Evening minimum	+0·6	8 P.M.	+1·2	6 P.M.	+1·2	7 P.M.	0	8 P.M.	+0·7	8 P.M.
Do. maximum	+1·8	Midnight	+1·4	9 P.M.	+1·6	10 P.M.	+0·2	10 P.M.	+0·9	9 P.M.

The mean maximum and minimum temperature gradients down the Gangetic Plain during the mean day of April and the hours of their occurrence are:—

Phase.	Epoch.	Mean temperature gradient in degrees per 100 miles.
Morning minimum	5 A.M.	+0·5
Do. maximum	10 A.M.	+2·2
Evening minimum	7 P.M.	+0·7
Do. maximum	10 P.M.	+1·1

The gradients have hence a double oscillation. The increase of gradients in the morning is due to the earlier heating of the ground surface and superincumbent air by the solar action at the eastern than the western stations, and the decrease of the gradients from 2 to 6 P.M. to the reverse action in the afternoon, *viz.*, the earlier cooling of the air at the eastern stations. The increase between 8 and 10 P.M., which it will be seen is shown over the whole area from Allahabad to Lahore, is due to the fact that the rate of cooling of the air has its maximum value at 6 to 7 P.M. (local time), and that it diminishes rapidly in amount during the next three hours, as is shown by the following data:—

Hourly interval, Local time.	Change of temperature during hourly intervals, 3 P.M. to midnight during March to May at			
	Allahabad.	Lucknow.	Roorkee.	Lahore.
	°	°	°	°
3—4 P.M.	—1·09	—0·81	—0·88	—0·77
4—5 „	—2·85	—2·53	—2·10	—2·25
5—6 „	—4·03	—3·66	—3·24	—3·35
6—7 „	—4·10	—3·82	—3·77	—3·58
7—8 „	—3·30	—3·27	—3·34	—3·11
8—9 „	—2·34	—2·56	—2·34	—2·38
9—10 „	—1·76	—2·05	—1·66	—1·78
10—11 „	—1·54	—1·69	—1·60	—1·41
11—Midnight	—1·38	—1·27	—1·72	—1·11

Hourly interval, Local time.	Change of temperature during hourly intervals, 3 P.M. to midnight in April at			
	Allahabad.	Lucknow.	Roorkee.	Lahore.
	°	°	°	°
3—4 P.M.	—1·04	—0·92	—0·85	—0·80
4—5 „	—3·00	—2·80	—2·14	—2·27
5—6 „	—4·33	—4·01	—3·40	—3·42
6—7 „	—4·43	—4·15	—4·01	—3·74
7—8 „	—3·56	—3·56	—3·48	—3·24
8—9 „	—2·50	—2·83	—2·40	—2·39
9—10 „	—1·84	—2·27	—1·71	—1·65
10—11 „	—1·55	—1·79	—1·78	—1·23
11—Midnight	—1·36	—1·25	—1·94	—1·02

Hence, considering two places, one of which is fifteen degrees, or one hour of time, to the west of the other (subject to the laws of diurnal variation given for Allahabad and Lahore in the last table), whilst temperature at the eastern station on the mean day in April was decreasing 3°·6 between 7 and 8 P.M., it would be decreasing 3°·7 at the western station during the same interval of time (corresponding to the period between 6 and 7 P.M,

local time). Similarly whilst it was decreasing $2^{\circ}{\cdot}5$ at the eastern station between 8 and 9 P.M., it would be decreasing $3^{\circ}{\cdot}2$ at the western station during the same interval (corresponding to that between 7 and 8 P.M. local time). The differences of temperature, in the case when the eastern station is warmer (as in Northern India), would hence increase to a slight extent during these hourly intervals, due to the greater fall at the western than the eastern station. The relative differences of temperature would hence increase during the evening hours, and similar considerations show that they would decrease slightly during the early morning hours, thus giving rise to an oscillatory change of small amplitude. This second or night oscillation, due to the varying rate of change of temperature, is, like the first, a result of the considerable differences of longitude of stations in the Gangetic Plain. It is evident that the actual temperature differences can be obtained most easily by taking the curves of Allahabad and Lahore and displacing the latter to the right by an interval of thirty minutes corresponding to the difference of longitude of the two places as is done in figure 5, Plate XXX, and similarly for the other pairs of stations for which curves are given in figs. 6 to 8 of the same plate.

The correspondence between the temperature gradients and the diurnal variation of the wind is very marked, as is shown by the following comparison :—

(1) The temperature gradients and the air movement have each a double oscillation during the day, *viz.*, a strongly-marked day oscillation and a feeble night oscillation.

(2) The epochs of the maximum and minimum values of these two elements are also directly related. The following gives data for comparison :—

Phase.	Epoch of phase of	
	Wind intensity.	Temperature gradients.
Maximum	about midnight.	10 P.M.
Minimum	7 A.M.	5 A.M.
Maximum	2 P.M.	10 "
Minimum	7 to 10 "	7 P.M.

The preceding data show that the epochs of the maximum and minimum temperature gradients in every case precede those of the corresponding epochs of the diurnal air movement and by nearly equal time intervals.

(3) The rate of most rapid increase of the air movement in the morning is between 8 and 11 A.M. and coincides with the epoch or period of the greatest temperature gradients, and the rate of most rapid decrease is between 5 P.M. and 8 P.M. and is hence simultaneous with the period of minimum temperature gradients.

There is hence a clearly marked relation between the variations of the temperature gradients and of the air movement in the Gangetic Plain during the day, and it is hence certain that the temperature conditions play an important part in determining the air movement.

Another feature, parallel with the large day oscillation of the temperature gra-

dients, is the difference of temperature between the ground and the air at 4 feet above the surface. This varies very considerably in amount, and is subject to a day oscillation of large amplitude.

Data have been given in pages 195-6, showing the large increase in the vertical temperature gradients near the earth's surface from January to May when they have their maximum value in the Gangetic Plain.

The following data, derived from observations taken at Allahabad, Jeypore and Lahore, in the year 1894, illustrate this feature more fully :—

TABLE XXV.—*Differences between ground surface temperature and temperature of the air four feet above the ground.*

Station.	Month	6 hours.	14 hours	22 hours
		°	°	°
Allahabad	January	−4·5	+7·5	−5·4
	February	−4·1	+14·2	−4·4
	March	−5·8	+29·4	−6·4
	April	−6·1	+32·9	−7·3
	May	−4·1	+33·3	−6·7

Station	Month	4 hours	10 hours	16 hours	22 hours
		°	°	°	°
Jeypore .	January	−7·3	+15·8	+11·9	−7·0
	February . . .	−8·4	+20·3	+19·3	−8·0
	March	−11·7	+29·3	+24·8	−11·1
	April	−11·8	+35·5	+26·6	−10·9
	May	−9·3	+32·1	+25·6	−8·6

Station	Month	6 hours.	10 hours	16 hours	22 hours.
		°	°	°	°
Lahore .	January . . .	−4·7	+3·3	−2·0	−5·2
	February	−5·0	+2·8	+3·5	−4·5
	March . . .	−5·2	+17·2	+11·9	−4·7
	April	−6·0	+28·1	+22·5	−6·4
	May	−5·1	+31·2	+25·0	−6·0

The preceding data indicate that the surface is always cooler than the air at 4 feet above it during the night and early morning hours in the dry monsoon. The vertical temperature differences are, so far as can be judged from the data, very uniform during the night hours, and at different places. Thus, at Allahabad the differences average 5°·5 during the night and early morning hours, and at Lahore they are the same in average amount. The hourly differences increase rapidly in the hot weather from 8 A.M. to about

noon, and the maximum diurnal differences increase very rapidly with the season from January to May. Thus at Allahabad the 2 P.M. differences increase from 7° in January to 33° in May, and at Jeypore the 10 A.M. differences increase from an average of 15°·8 in January to 35°·5 in April.

The Lahore data are very interesting, as they show that the ground is, on the average, cooler throughout the whole day than the air at 4 feet elevation during the months of December and January (as is also the case in November). It is not possible to decide from the available data whether this is a mere local peculiarity or whether it is a general condition of the month in the North and Central Punjab. Considering the extreme lightness of the winds in that area in January, it is most probably a general condition.

I have, whilst this paper was passing through the press, been furnished, by the kindness of Surgeon-Colonel T. H. Hendley, Superintendent of the Maharaja's observatory, Jeypore, with a series of hourly observations of the ground surface temperature at that station. The following is a summary of these data for the first five months of the year 1885:—

Mean difference of temperature between the ground surface and the air four feet above the ground at Jeypore.

Month.	Difference, ground surface (a) and air temperature (b) in shade (a)—(b).												
	6 A.M.	7 A.M.	8 A.M.	9 A.M.	10 A.M.	11 A.M.	Noon.	1 P.M.	2 P.M.	3 P.M.	4 P.M.	5 P.M.	6 P.M.
	°	°	°	°	°	°	°	°	°	°	°	°	°
January 1885 . .	−3·8	−3·8	−3·4	+3·1	+10·7	+17·8	+21·7	+21·0	+19·4	+13·7	+9·0	+1·4	−2·2
February „ . .	−9·8	−9·8	−3·3	+7·8	+18·9	+30·2	+35·5	+37·7	+36·1	+31·1	+21·2	+8·2	−2·0
March „ . .	−10·2	−6·6	+4·1	+15·7	+25·6	+37·9	+41·3	+42·7	+37·7	+28·7	+21·3	+10·2	+0·6
April „ . .	−7·7	−1·6	+10·8	+18·9	+25·1	+37·6	+38·7	+38·8	+32·1	+24·8	+13·6	+5·0	+0·6
May „ . .	−5·3	+1·5	+13·2	+23·1	+30·7	+34·8	+39·8	+43·0	+40·4	+31·9	+20·0	+10·4	+6·0

The preceding data are for apparent mean time. They are interesting as they show that the greatest heating of the ground occurs very approximately between noon and 1 P.M. and that the difference between the temperature of the ground surface and of the air at 4 feet above is very large in the hot weather and probably occasionably exceeds 50° on the most favourable days.

The temperature conditions near the earth's surface in the hot weather during the day hours are such as are incompatible with stable equilibrium. Convective action is hence an essential feature of the air movement during the day hours. The intensity and volume of the convective motion increase from January to May. It has a strongly marked diurnal variation as it commences about 8 or 9 A.M., attains its maximum about noon or 1 P.M. and decreases until about 5 or 6 P.M., when it ceases in the lower strata. The intensity, and therefore the height of the convective movement, increases during the morning hours, and hence the corresponding down-rush brings air from higher and increasing elevations. This is undoubtedly one cause of the increase of velocity during the morning hours. The diurnal variation of the convective movement hence runs parallel with that of the horizontal air movement in the Gangetic Plain, and is evidently either directly or indirectly related to the vertical temperature differences or gradients in the lowest air stratum, as measured by the methods employed above.

A feature of the temperature conditions closely related to the above is the rapid decrease of temperature with elevation in the lower atmospheric strata during the day hours in the Gangetic Plain. This feature has been fully dealt with (so far as that was possible with the available data) by Hill. No further data have been obtained since, and his conclusions give the whole of the present information, and are summarized below:—

1st.—The decrement of temperature near the ground on fine clear days is most probably more rapid in India than in England.

2nd.—The temperature at the hottest time of the day decreases $1^{\circ}{\cdot}4$ Fahr. between 4 and 40 feet of elevation from the ground at Calcutta in the most serene months, or at the rate of $38^{\circ}{\cdot}9$ per 1,000 feet.

3rd.—The temperature decrement with elevation is probably greater in Central India and the Gangetic Plain than in Bengal.

As this rapid decrease of temperature in the lowest stratum is an immediate effect of the heating of the earth's surface, it is probably most satisfactory to adopt the actual temperature differences between the ground and the air at 4 feet above it as a rough measurement of the intensity of the actions which give rise to the convective movements that occur during the hot weather period.

A consideration of the curves in Plates XXVI and XXX, giving the diurnal variation of the winds at stations in Northern India, indicates most clearly that the mean air movement in the hot weather, and also the air movement of the hot winds, is cumulative down the Gangetic Plain and reaches its greatest intensity probably in the eastern districts of the North-Western Provinces and Central or South Bihar. It is hence evident that a large proportion of the motion must be due to forces or actions which have a cumulative or accelerating effect in a horizontal direction from west to east. This portion of the motion cannot be explained by a general descent of air (say from 10,000 feet) over the Gangetic Plain. This accelerating movement down the Gangetic Plain to Central Bihar is an immediate consequence of the fact that the latter area is a thermal sink. It is the hottest area in the Indo-Gangetic Plain in April and May, being hotter than all neighbouring areas throughout the whole day, the temperature gradients towards it varying considerably during the day in consequence chiefly of longitude differences. As a result of the permanent high temperature in April and May, pressure is slightly lower in this area than elsewhere in Northern India, and there is a more or less regular cyclonic circulation over it, as is shown by the following mean wind directions for April and May:—

Station.	Normal mean wind direction.	
	April.	May.
Saugor Island	SSW	SSW
Berhampore	SSW	SE
Malda	SE	E
Dinajpur	E	E
Purnea	NE	E
Gorakhpur	WNW	E

Station.	Normal mean wind direction.	
	April.	May.
Allahabad	NW	N
Sutna	WNW	NW
Jubbulpore	WNW	WNW
Sambalpur	W	WSW
Hazaribagh	WNW	WSW

Temperature is slightly higher in Central Bihar and the eastern districts of the North-Western Provinces in the months of March, April and May than in Bengal, or in the western half of the Gangetic Plain or the Punjab. This feature is most pronounced, it may be noted, when the hot winds blow most strongly. This hot area is also the goal or centre of the wind aspiration of the period; westerly winds blowing down the Gangetic Plain, southerly winds in South and West Bengal, and easterly winds in North Bengal and Assam towards it.

The depression in the sink and the gradients in the neighbourhood are undoubtedly small in amount, but this is a characteristic of low pressure areas or sinks due to purely thermal actions or temperature differences, in which there is no increase of energy due to the condensation of aqueous vapour, as, for example, in the *quasi* permanent sink in Sind during the period May to September, due to the high temperature over Upper Sind, and more especially the Kachhi desert. The Central Bihar and Chota Nagpur thermal sink is very persistent during the hot weather.

The preceding remarks indicate that the hot winds of the Gangetic Plain are directed towards a thermal sink or area of persistent high temperature and low pressure. The dynamics of a hot area (relatively to neighbouring districts) have been worked out more or less fully by various meteorological writers. Over any large area in which temperature is higher than in neighbouring districts, there is necessarily a large vertical or ascensional movement of the air in addition to general expansion or to irregular local convective movements. The uptake over the hot area determines or accompanies an outflow above and an inflow below. The whole of this movement gives rise to an area of slight barometric depression in which a cyclonic circulation of greater or less regularity obtains.

In the present instance, the hot area is the field of a persistent cyclonic circulation during the months of April and May, the intensity of which has a marked diurnal variation. This variation, of course, depends to a large extent upon the fact that the temperature gradients in the Gangetic Plain differ very considerably during the day. It has already been shown that the intensity of the winds in the Gangetic Plain or of the indraught down the Gangetic Plain towards the hot area and the temperature gradients go through a double oscillation daily, and that the period and amplitude of the oscillation of the temperature gradients correspond to those of the air movement, and are hence probably related to the latter as causes. Experience in India has established that the gradients in thermal depressions, in which there is little or no formation of cloud, are almost invariably feeble, and the Sind depression during the hot weather months is a striking example of this fact. The smallness of the depression in the Central Bihar hot area is hence an evidence of its probable origin, *viz.*, as a thermal sink.

An important effect of the diurnal variation of temperature is an expansional movement during the period of increasing temperature and a contractional movement during the period of decreasing temperature of the whole mass of air over the land area in the tropics. This effect of the sun's heat on the lower atmospheric strata is frequently described as the transmission of a wave from east to west. It gives rise to an oscillatory movement of the atmosphere in the vertical direction, and hence to the transmission of a wave of condensation and rarefaction from east to west.

There are several points in connection with this movement, the discussion of which will help to elucidate the phenomena and causes of the hot winds in Northern India.

If the whole of the solar heat during the day were absorbed by the atmosphere, and absorption were proportional to density, it would in the tropics raise the temperature of the whole depth of atmosphere by about 8° C. As only one-fourth of the sun's heat is absorbed in its progress through the atmosphere, the result of the absorption of that amount of heat during the day on the preceding supposition would be a total daily increase of temperature of 2° C. or between 3° and 4° Fahr., which is very nearly the diurnal temperature variation of the air over large sea areas in the tropics during fine clear weather.

The diurnal range of temperature at and near the earth's surface is very much greater, averaging 27° Fahr., near the earth's surface in the Gangetic Plain during the hot weather. It diminishes upwards to a total of perhaps 3° or 4° Fahr. The additional heat required to increase the temperature of the air near the ground to such an extent as to give a diurnal range of 27° is derived indirectly from the sun through the action of the earth's surface. This increase of temperature (*viz.*, of 27° between 6 A.M. and 2 P.M.) would in the Gangetic Plain, if the air were not permitted to expand in any direction, give rise to a large increase of pressure, averaging nearly two inches in amount. No such increase of pressure actually occurs.

The large diurnal increase of temperature between 6 A.M. and 2 P.M., averaging nearly 27° in the dry monsoon in Northern India, takes place under various meteorological conditions. For example, in the month of November it accompanies very feeble air movement over the whole of the Punjab and North-Western Provinces, the total amount in 24 hours, as registered by the anemometers in use at the observing stations over the whole of that area, being frequently less than 20 miles in 24 hours. The large diurnal variation of temperature and readjustment of pressure hence occur for a considerable period of the year with little or no horizontal air movement. It may, on the other hand, as during the months of April and May, be associated with very large and rapid horizontal air movements. The readjustment of the pressure conditions in the lower atmosphere following this diurnal temperature disturbance however takes place as rapidly and fully on the days of the feeblest, as on those of the strongest, horizontal air movement in the dry monsoon, and hence must be mainly and primarily due to movement in the vertical direction, which may be either expansional or convective. Convective movements undoubtedly occur very largely during the hot weather months, but they are almost entirely absent in the months of December and January in Upper India. It is hence certain that the only form of movement, on the large scale, over the whole of Northern India, which invariably accompanies the daily heating of the lowest strata of the atmosphere by the direct and indirect action of the sun is expansional, and that it is by this movement that the readjustment of pressure towards equilibrium of the lowest stratum of the air, disturbed by the large changes of temperature conditions near the earth's surface, is mainly effected.

As already stated, the increase of temperature of the lowest stratum of air nearest the earth's surface between 6 A.M. and 2 P.M., would, if there were no movement in any direction, increase the pressure by over two inches. Pressure actually decreases by moderately small amounts, averaging about a tenth of an inch, during that interval over the greater part of Northern India. This actual change is only 5 per cent. of the change possible under the condition stated above, and is in the opposite direction. Neglecting this small change at present, it is certain that the diurnal rise of temperature accompanies or is followed by an upheaval of the isobars, and that the air between the surface of the earth and any isobar of given value increases in thickness or elevation during the morning hours. The actual expansion of any given mass of air, the upper surface of which is defined by a given isobar, can be calculated on suitable suppositions. It is probably small in amount, not more than a few hundred feet for a thickness of three or four miles of air. This movement takes place so slowly during the course of several hours that it does not affect the pressure at and near the earth's surface, which is hence, so far as this movement is concerned, measured statically by the gravitational effect of the mass. Hence this expansional movement does not affect pressure directly. It however affects pressure indirectly by giving rise to horizontal air movements which increase or diminish the mass of air over a given portion of the earth's surface according to its position with respect to the heated air. As the expansional movement is cumulative for several hours, and hence unequal in total amount at places in different longitudes at the same instant, it modifies the shape of the isobars, so that they deviate more and more from the surfaces of equal potential for the gravitational force of the earth, and there hence result movements down the slopes of the isobaric surfaces.

The effect of this increase of temperature near the earth's surface in the earlier morning hours (7 to 9 A.M.) is probably chiefly expansional, and hence occurs with little or no change of pressure. The expansion however modifies the isobaric surfaces in the higher regions so that they are no longer surfaces of equilibrium for the gravitational forces, and hence the air begins to move away from the area of increasing temperature in the higher regions, and since a similar effect has already been set up to the east and is still in progress this occurs chiefly to the west. This outflow gives rise to a general local decrease of pressure and also tends to increase the expansional movement and to set up an uptake or ascensional movement over the area of rapidly increasing temperature. This goes on with increasing activity until the time of maximum temperature during the day or shortly afterwards.

The horizontal movements described above follow as a result of the expansional movement and may hence be described as secondary effects. Their tendency is to diminish the mass of air over the heated area, and hence to decrease pressure to a slight extent. The general effect of these movements is to give rise to a wave of low or slightly deficient pressure over a considerable breadth of country near the crest of the heat wave and to a wave of slightly increased pressure at some distance in front and also to another in the rear.

It is important to note that the air movement due to these actions occurs chiefly in the higher atmospheric strata, and that it is probable any secondary effect, such as, *e.g.*, change of pressure due to this movement, will be small.

It is hence clear that neither a high temperature nor a large diurnal range of temperature is necessarily an effective cause of horizontal air movement near the earth's surface. In the dry weather months of January to April and May when skies are generally quite free from cloud, the conclusions stated above apply directly to the pressure conditions.

It is not necessary to work out this part of the subject in more detail in the present paper. The main object of the preceding remarks is to show that the large diurnal changes of temperature give rise in the first place to a series of waves advancing in a westward direction through the atmosphere, due to condensation and rarefaction of the *whole* mass of the atmosphere, and that the passage of these local waves does not affect he pressure of the air near the earth's surface directly, but only indirectly by giving rise to movements chiefly in the higher atmospheric strata which at one period of the day increase and at another decrease the mass of air over any given portion of the earth's surface to a comparatively small extent and hence alter pressure only to a slight amount.

It is also important to consider the pressure effects of the small but numerous convective movements set up by large local horizontal and vertical temperature differences or gradients. In consequence of the unequal heating of the ground and hence also of the superincumbent air, small convective movements are originated. The upward movement of such currents is frequently made visible by the dust carried up. These local convective movements, when they are rapid, are known as dust-whirls, devils, etc., in Northern India and are exceedingly common in the Gangetic Plain in April and May, more especially in the morning hours from about 9 to noon. It is certain that these upward movements form only a portion of the total convective action, and that there is much downward movement corresponding in character and amount to the upward movement. The total amount of the upward movement during any interval over any given large area probably differs little from the total downward movement. The effect of the rising portion of any of these convective movements in diminishing pressure at any point at a considerable distance from it, is almost certainly partially, if not entirely, counterbalanced by the effect of the downward movement of the other portion of the convective flow. Hence also the total pressure effect at any instant, due to the numerous convective whirls in progress in the neighbourhood of any place, will be practically *nil*. It is probably due to this that the diurnal changes of pressure proceed as regularly and smoothly in the hot weather as in the cold weather months in the Gangetic Plain. In fact, the traces of the autographic instruments at Calcutta or Lahore on days in the hot weather, except those on which thunderstorms and duststorms occur, are as smooth and regular as the curves obtained from long series of observations, smoothed by Bessel's formula. Although these convective movements do not modify pressure, they have an important effect on the horizontal air movement, as the air rising up is replaced by air from above with a greater horizontal velocity than that which it replaces.

These convective movements hence tend to increase considerably the lower air movement, although they do not increase the lower air pressure or gradients. This result is in accord with the experience that the dry hot winds are not directly related to the horizontal pressure gradients at the level of the earth's surface.

It may be further pointed out that some of the preceding conclusions have an important bearing upon the formation of low pressure areas. In the initial stage it is probable that there are numerous small upward movements. In such cases there is little or no perceptible pressure effect at the surface of the earth. If these upward convective movements increase in volume and amalgamate or extend over a large area, a general fall of pressure begins, and a low pressure area forms and develops until it attains a maximum intensity determined by the various conditions and actions contributing towards its growth.

The preceding remarks have indicated roughly the general manner in which pressure is modified in Northern India by certain temperature conditions and the resulting air movements during the hot weather.

The mean aqueous vapour pressure data, showing the diurnal variation between 10 A.M. and 4 P.M. in the month of April, given in page 180, indicate that the amount of vapour at stations in the Gangetic Plain decreases during the day hours from 9 A.M. to about 3 P.M., and afterwards increases, and that this oscillatory change is of moderate magnitude. The westerly movement down the Gangetic Plain transfers air from the drier to the more humid districts, and hence tends to diminish the aqueous vapour pressure during the day hours of large air movement. The decrease of the aqueous vapour pressure is, relatively to the actual amount, considerably greater than the decrease in the air pressure due to the expansional and convective movements accompanying the large day increase of temperature. The preceding suggestion accounts for a portion of the change, but probably less than a half as stated in page 176. A comparison of the actual vapour pressure data of Allahabad and Patna for the 7th of May 1883 (*vide* pages 193-4) with the average or normal data for the same stations shows that the normal data omit some of the most characteristic features of that element of observation on days when the hot winds blow strongly.

For example, in North and Central Bihar (represented by Patna) an alternation of westerly and easterly winds, such as frequently obtains during the day in May, is accompanied with very large and rapid changes of the aqueous vapour pressure at the critical hours of shift of wind from a land to a sea direction and *vice versâ*. Again the data of the 7th of May 1883 establish that an important feature at Allahabad is the rapid fluctuation of the aqueous vapour pressure during the day, indicating that the moving air in its passage over the observatory varies very largely and rapidly in its hygrometric state. The air is hence, during the day period when convection is most rapid, very imperfectly mixed, masses of air of different hygrometric conditions being frequently in close proximity and passing in rapid succession over the place of observation.

The usual explanation of the decrease of aqueous vapour pressure during the day hours from 9 A.M. to 3 P.M. at Allahabad and other stations in the Gangetic Plain is that the air brought down by the convective actions or processes is much drier than the rising air it replaces. But the ordinary explanation given of this process is not quite satisfactory. If, as is apparently assumed, the convective movement is under ordinary conditions in the hot weather in Northern India (*i.e.*, on days when skies are clear and no cloud is formed), except over the higher snow-clad elevations of the Himalayas, practically a cyclical process, it is not easy to account for the descending air in this approximately perfect cyclical process being so much drier than the ascending air at the same elevation. The only explanation I can at present suggest is, that there is, during the hot weather period, an air movement from the Himalayan region at such an elevation as to introduce a certain amount of very dry air daily during the period 9 A.M. to 3 or 4 P.M. from the Thibetan area.

As has been indicated in the preceding paragraph, the air movement between the Himalayan area and the Gangetic Plain may be an important factor of the general air movement over Northern India during the hot weather period. The following gives the results of my observations of that movement at Simla. During the day hours there is a general movement from the south across the lower hills up to the first line of and probably up

to the central mass of the snows. The true character of this movement is shown by the daily formation of cloud in fine weather over the first line of snows which commences between 9 to 10 A.M., as seen, from Simla. The cloud increases in thickness for some hours, and extends southwards towards the plains to which it is evidently drifted by an upper return current.

The cloud begins to decrease in amount in the afternoon about 3 P.M., and the snows, which are almost invariably concealed by clouds in ordinary fine weather from 10 A.M. to 4 P.M., again become visible a short time before sunset. The diurnal variation of the strength of the winds and the formation and movement of clouds in the Himalayan districts during the hot weather are strongly in favour of the supposition that, during the day, there is a flow from the plains to the hills in the lower atmosphere, partially or completely compensated by a return movement from the hills to the plains in the middle or higher atmospheric strata, and that the uptake, by which the lower air movement is changed into an upper return current, occurs chiefly over the higher snow ranges.

The chief cause of this circulation during the day hours is probably the rapid heating of the ground surface and adjacent atmospheric strata in the lower hills below the level of the permanent snow line above which the solar action has little effect in increasing temperature. Other actions contribute, as, for example, the probably relatively higher pressure during the day hours at the same level over the snow-clad surface of the inner Himalayas, than at the same level over the plains.

The interchange of air between the hills and plains in Northern India during the night hours is the opposite to that of the day hours; in other words, there is a general movement in the lower strata from the hills to the plains and in the higher strata from the plains to the hills. The air cools down more rapidly over the hills than over the plains, and it hence drifts down towards the plains, where it then merges into the feeble easterly drift of the plains. The movement from the higher to the lower levels is strongly marked in the valleys, especially in those of a funnel shape. The up per return movement is indicated by theory and confirmed by certain special features of the temperature conditions at the hill stations.

In addition to the above movement which is common to the whole Himalayan area, there is a special action in the Sikkim hill district. These hills are to the north of the permanent hot area in Central Bihar, over which there is a large general ascensional and descensional movement during the day. The descensional movement is accompanied by a very strong flow from the Sikkim hills, and hence the extraordinarily strong winds recorded in the late afternoon and evening hours at Darjeeling as indicated by the data in page 178.

It is, so far as I can judge, almost certain that the variations of the amount of aqueous vapour pressure present do not contribute directly as a cause to the air movement of this period. These variations, however, undoubtedly serve to indicate to some extent the character and direction of the air movement, more especially in the higher strata.

The discussion has hence established that the air movement in Northern India during the hot weather is a result of the following conditions or actions :—

1st.—The air movement is in part due to a persistent shallow low pressure area of relatively high temperature in Central and South Bihar, Chota Nagpur and the eastern districts of the North-Western Provinces, its origin and

maintenance being due to thermal actions. The gradients in the Gangetic Plain due to this are small but nearly constant in mean amount during the period from January to April or May, and have a well marked diurnal variation. The part of the air movement due to this cause is probably directly related to the gradients. The relation could probably be ascertained from the consideration of the air movement in the Gangetic Plain on selected days in the months of November and December.

2nd.—The air movement in the hot weather is in part due to convective actions, by which air with greater velocity is brought down from above to replace air of less velocity rising from below. This part of the air movement has no relation to the horizontal pressure gradients, and is probably related chiefly to the temperature gradients in the lowest stratum or the difference between the ground-surface temperature and the temperature of the air at a given elevation, as for example, 4 feet; but it may be dependent to a slight extent upon the amount of moisture in the air and other causes which affect its buoyancy.

3rd.—The air movement in the Gangetic Plain is also modified by the presence of the neighbouring mass of the Himalayan mountain ranges. There is a considerable interchange between the plains and mountains which not only varies largely in volume and intensity during the day, but is also oscillatory in character, the movement in the night hours being opposite in direction to that of the day hours. It is possible, if not probable, that in virtue of this movement there may be an indraught of dry air from Thibet to India during the day in the hot weather and if so, this indraught will explain certain anomalous features in the diurnal variation of aqueous vapour pressure in the Gangetic Plain.

The discussion has also shown that on the days when true "hot winds" obtain in the Gangetic Plain, the temperature and pressure conditions are similar in character to the mean conditions of the month the relations of which to the mean winds of the period have been fully stated, but are more intense and massive. Thus it has been proved—

1st.—That the temperature in the Bihar thermal sink is excessive at such times and may be from 10° to 12° above the normal temperature of the period.

2nd.—That the temperature gradients down the Gangetic Plain and between the Bengal coast and Central Bihar are considerably greater than the normal.

3rd.—That the barometric depression in Bihar is more strongly marked than usual.

4th.—That the vertical temperature gradients are considerably steeper than usual.

5th.—That the convective movements, as indicated by the air movement at Darjeeling and other hill stations, are more vigorous than usual.

The only important difference between the normal pressure conditions of the hot weather and the pressure conditions of the periods of vigorous hot winds is that the Bihar and Chota Nagpur low pressure area or thermal sink is usually displaced northwards to the foot of the hills in Bihar and North Bengal. Steep gradients for westerly winds usually obtain under these conditions over nearly the whole of Northern and Central

India. The gradients alter so quickly during the day that it is not possible to judge of their character and diurnal variation from mean data or the data for one hour (*viz.*, 8 A.M.). Hence the necessity for additional data. It will probably be possible by hourly simultaneous observations taken at short intervals at a considerable number of stations to obtain accurate data of the meteorological conditions accompanying these winds, and arrangements have been made to obtain such data during the next two years. The accumulation of data will, it is hoped, not only throw further light on the phenomena of these winds, but also enable the intensity and effect of each of the actions or factors contributing to their strength to be separately estimated and the relative importance of each factor to be gauged.

V.—An account of a storm developed in Equatorial Regions, by W. L. DALLAS, ESQ., *Assistant Meteorological Reporter to the Government of India.*

Here in India, where the study of cyclone formation and development has been followed with the greatest minuteness under exceptionally favourable conditions, condensation phenomena have been shown to exert an altogether overwhelming influence on the production and formation of cyclones. In all cases of cyclone formation certain antecedent conditions have formed an invariable adjunct to the appearance of a cyclone. These conditions are found when from any cause is produced an area of uniformity of pressure, of gentle winds, local rather than general in their character, over a region where constant evaporation can proceed unchecked. Hence Mr. Eliot has laid it down as a general principle "that if over any area of constant evaporation there is not for any considerable time an atmospheric current of sufficient intensity to carry off the aqueous vapour as fast as it is produced condensation must occur over the producing area, and also that the process of evaporation and subsequent condensation will be accompanied with the formation of an area of diminishing atmospheric pressure." Such areas have constantly been shown to exist prior to the appearance of cyclones both in the Arabian Sea and in the Bay of Bengal, and within them has proceeded a constant process of absorption of heat and consequently of mechanical energy by the overlying atmosphere. It is possible of course to argue that within such an area, there being no horizontal outflow for the accumulating aqueous vapour, over a uniform surface like the water surface of the Bay of Bengal, the evaporating effect of the solar heat might theoretically be equal throughout, that the air within such a region might ascend to a uniform height throughout, and that condensation of invisible aqueous vapour into visible cloud might occur at the same level throughout. Could such a condition actually occur it would probably be a requisite condition of cyclone formation that a force analogous to the explosion of a charge of gunpowder by a cap should give an impulse to a particular portion of the system in order to centralize the potential energy contained in the atmosphere. In practice, however, this dead level action never occurs, but the uniformity is broken up by slight local irregularities of which the less important form the foci of the small squalls which are frequently experienced during the period preceding the appearance of a cyclone, and the most important forms the centre of the main cyclone. The late Mr. Blanford supposed that the actual formation (of a cyclone) is finally determined by the inrush of a saturated stormy current from the south-west. This supposition is almost certainly incorrect, as there can be no question that however powerful may be the effect of such a current on the maintenance of a once-formed cyclone the inrush of a stormy current during the period of genesis of a cyclone cannot be other than fatal to the initiation of a storm in whatever manner we may suppose this to originate.

As opposed to the above it would appear that the ordinary assumption as to the conditions antecedent to the appearance of a cyclone as described by Professor Ferrel and other American meteorologists is briefly as follows:—A general uniformity of pressure and quietness in the atmosphere over the sea surface. Light local breezes but no steady or general air current. This quiet air becomes warm and moist, clouds form and within this cloud region some local temperature disturbance causes an initial ascending current. As Ferrel has pointed out "the complete temperature conditions of a cyclone rarely extend down to the earth's surface,

but the interchanging and gyratory motions, commencing first up in the cloud regions, are soon propagated downwards to the earth's surface by the action, through friction of the upper strata upon the lower ones." When this movement has been once started the pressure in the lower strata of the atmosphere slackens and these air strata tend naturally to rise up, the space formerly occupied by them being taken up by the inflowing air from surrounding regions. This inflowing air is "necessarily drawn also into a gyration around the centre." The above is the ordinary view of cyclone generation, but it is necessary, in order to explain the object of the following investigation, to discuss this subject in somewhat greater detail and to give some quotations in full from the writings of meteorological authorities dealing with the subject of cyclone formation. Professor Ferrel writes (Rept. Ch. Sig. Officer, 1885, p. 244). "The force which overcomes the inertia and friction of the gyratory motion of any part of the air is obtained from—

$$0=(2n\cos\psi+\nu)\,u+\frac{dv}{dt}+F_v)$$

which may be put in the following form:—

$$\frac{dv}{dt}+F_v=-(2n\cos\psi+\nu)\,u$$

in which the last member is the force which overcomes the inertia and friction expressed by the first member.......... This force, it is seen, depends upon u, and the earth's rotation, so that without a motion to or from the centre and without rotation of the earth on its axis, there is no force to give rise to a gyratory motion, for ν only acquires a value after this motion has once set in. Since, also, cos ψ vanishes on the equator, there can be no gyratory motion there in any case."

"They (tropical cyclones) seem to originate at the northern limit of the calm belt *only*, or at least not so far within, that the deflecting force depending upon the earth's rotation is too small to produce gyrations, for as we have seen this force becomes very small near to and vanishes at the equator..... The Trade Winds blow down to a latitude where the deflecting force of the earth's rotation is too weak to give rise to cyclones." (*Idem*, p. 264.)

"If the earth had no rotation on its axis, the air, in its vertical circulation, in all cases of local and temporary disturbances, would move in the lower strata directly towards the central part of the area of higher temperature and less pressure....... and there would be no gyratory motion around the centre" (Popular Treatise on the Winds, p. 242).

Again in Professor W. M. Davis' Elementary Meteorology (p. 197) it is stated "Tropical cyclones being essentially vorticular storms a sufficient explanation of their occurrence only when their place of origin is removed from the equator must have already come to mind from the account of the deflecting action of the earth's rotation. Instability and convection occur in the doldrums at all seasons...... but the establishment of a convectional whirl with a definite direction of rotation can only take place when the doldrums are far enough from the equator to give the deflecting force an effective value." Again on p. 189 it is stated that "if the circular component of the wind's motion were absent and the air moved simply as a radial inflow instead of in a spiral whirl its velocity would be so moderate that it would not reach the violence of a storm wind."

The above quotations indicate the opinions of these eminent authorities and show (1) that the origin of a cyclone depends on a temperature inequality which determines a flow of air towards a centre; (2) that were this flow to take place radially the disappearance of the inequality would take place without any considerable atmospheric disturbance; (3) that the gyratory motions which appear in a cyclone depend for their origin on a force

arising from the rotation of the earth on its axis; and that (4) this force is very small near to and vanishes at the equator, and hence that at the equator there can be no gyratory motion around a centre in any case.

Having now stated the ordinarily received accounts of the origin of cyclones let us consider a very interesting series of weather changes which occurred over equatorial regions and the Bay of Bengal between the 1st and 15th of December 1894.

The following table gives the names of most of the vessels which were involved in the disturbance. These vessels were in every case traced to, or near, some station recording observations for the Indian Meteorological Department and the corrections applicable to the ships' barometers, given in the second column, were determined by inter-comparison between the barometric readings on board the ships and at these observatories. The positions at which, and the dates on which, these corrections were determined are given in the third and fourth columns. To say that even with these corrections applied, the barometric readings are often unsatisfactory is to state a truism with which every one who has dealt with marine meteorological logs is acquainted, but the observations in the present instance are certainly no better or worse than hundreds of similar observations which have been utilised to determine the course and intensity of storms at sea.

Name of Vessel.	Correction.	Determined by comparison with	On date.
Glencaird	+·050"	Lat. 11°46' N and Long. 91°17' E	12th.
Earl of Dunmore	No reading.	......	...
Andorinha	Do.	......	...
Talavera	0	Lat. 20°35' N and Long. 88°57' E	16th.
Falkenhurst	0	" 21° 2' N " 88°34' E	16th.
Pongola	+·050"	" 19°52' N " 87°46' E	6th.
City of Cambridge	+·050"	" 19°23' N " 87°24' E	4th.
Gulf Stream	0	" 21°33' N " 91°29' E	9th.
Zemindar	0	" 20°39' N " 85°39' E	17th.
Falls of Garry	0	" 10°49' N " 91°44' E	12th.
Rohilla	+·070"	Bombay	10th.
Kerbela	+·030"	Lat. 17°45' N and Long. 72°53' E	14th.
Congella	0	Negapatam	1st.
Queen Olga	+·140"	Saugor Island	10th.
Peninsular	0	Colombo	1st.
Inchbarra	0	Lat. 19°28' N and Long. 89°53' E	26th.
Vadala	+·150"	Ratnagiri	9th.
Clitus	+·050"	Do.	13th.
Purnea	0	Penang	1st.
Pentakota	0	Calcutta	1st.
Bhundara	+·100"	Saugor Island	11th.
Malda	+·030"	Diamond Harbour	12th.
Saint Hubert	+·110"	Colombo	6th.

Name of Vessel.	Correction.	Determined by comparison with	On date.
Nowshera	+·150"	Calicut	23rd.
Africa	+·120"	Rangoon	29th.
Chyebassa	+·070"	Cocanada	30th.
Choysang	—·050"	Singapore	8th.
Loodiana	0	Saugor Island	13th.
Sultan	No reading.	......	...
Landula	0	Penang	6th.
Virawa	+·040"	Colombo	5th.
Chelydra	—·010"	Calcutta	9th.
Morven	—·070"	Lat. 20°49′ N and Long. 89°17′ E	13th.

December 1st, 1894.

On December 1st the chart (Pl. XXXV) showed a long narrow low pressure area stretching from Longitude 65° E to Longitude 92° E and extending in its western parts between Latitudes 3° N and 5° S, in its central parts between Latitudes 3° N and 4°30′ S and in its eastern parts between Latitudes 7° N and 2° S. In southern latitudes pressure was exceptionally high and on both sides of the trough of low pressure the barometric gradients were moderately steep and the north-east trades on its northern side and the south-east trades on its southern side were moderate to fresh, while the weather was squally and rainy throughout. The following table gives the information shown graphically on the chart :—

Name of Vessel.	8 A.M. Position.		Barometer.			Wind		Weather.
	Lat.	Long. E.	Barometer.	Corrected.	Variation	Direction.	Force.	
	° ′	° ′	"	"	"			
S. Glencaird	9 50 S	92 15	29·785	29·835	+·085	SE	5	Clear. Midnight drizzling.
S. S. Jubeda	8 52 S	78 28	29·830	·830	—·070	SSE	4	Overcast.
S. Earl of Dunmore	7 41 S	90 18	..	...	...	ESE	4	Clear. 8 P.M., heavy rain squalls.
S. Andorina	6 28 S	87 59	...	..	...	E	4	Fine. 8 P.M., heavy clouds.
S. Talavera	2 3 S	79 12	765	·765	—·035	Var.	1	Overcast. 4 A.M., heavy rain.
S. Falconhurst	1 17 S	75 42	·805	·805	+·005	W	2	Fine. 4 P.M., squalls and rain.
S. S. Pongola	5 32 N	80 20	·765	29·815	—·085	NE	5	Fine. 4 P.M., squalls and rain.
S. S. City of Cambridge	6 50 N	81 59	·847	·847	—·053	N	2	Heavy rain squalls.
Barque Gulf Stream	7 26 N	89 28	·793	·793	—·107	NE by E	7	Ditto.
Pulu Bras (Coast of Sumatra)	*5 45 N*	*95 3*	...	...	...	E	...	
Baros (Coast of Sumatra)	*2 1 N*	*98 3*	...	...	...	SE	...	
Natal (Coast of Sumatra)	*0 33 N*	*99 6*	...	...	...	E	...	
Port Blair	...	...	·871	·863	—·061	NNE	6	Cloudy.
Camorta	...	...	·880	·850	?	E	...	Cloudy. Heavy rain during past 24 hours.

The first six ships were in south latitudes. The *Glencaird*, the *Earl of Dunmore* and the *Andorina* had south-easterly to easterly moderate to fresh winds with occasional squalls and rain; the *Talavera* and the *Falconhurst* had variable to light westerly winds with heavy rain and squalls. These two ships were within the low pressure area which lay between the currents of the Trades, and it is probable that the barometer reading on board

the *Falconhurst* was 0 05″ too high. The *Pongola*, the *City of Cambridge* and the *Gulf Stream* were in north latitudes They all three experienced northerly to north-easterly winds varying from a light breeze to a moderate gale with heavy squalls and rain. The reading recorded on board the *City of Cambridge* was 29 847″, which, according to the correction determined on the 4th at the head of the Bay, should be increased by 0 050″. But this ship on the 1st was close to the Ceylon coast, and it is obvious from a comparison of her barometric reading with those of Point de Galle, Trincomallee, etc., that the reading of 29·847″ is correct The observations from the north and west coasts of Sumatra, kindly supplied by Mr. Vander Stok, of the Batavia Observatory, show that the south-east Trades were blowing all over the Island of Sumatra as far north as Achin Head.

On the 1st then the chart (Pl XXXV) and table show that a trough of low pressure lay to the south of India, with its axis over the Equator, and that on either side the Trades were blowing strongly, while the weather was overcast, rainy and squally. The position of the trough over the Equator at the time that the sun was vertical over Lat 22° S was probably unusual

December 2nd—On the following day, December 2nd, the barometer had risen slightly over the Bay area and the Equatorial region to the south of the Bay, but the change had been uniform and the general conditions were little altered. The chart (Pl. XXXVI) showed the trough of low pressure to the south of Ceylon, but the central area of depression had changed somewhat and had assumed a more circular shape. The axis, however, still lay over the Equator, and the north-east and south-east Trades blew strongly on both sides of the depression. The following table gives the observations recorded around and within the central area —

Name of Vessel.	8 A M Position		Barometer			Wind		Weather
	Lat.	Long E.	Barometer	Corrected.	Variation	Direction	Force.	
	° ′	° ′	″	″	″			
S *Zemindar*	8 32 S	87 41	29·823	873	+ 123	SE	3	Squally
S *Falls of Garry*	7 54 S	92 0	786	886	+ 136	ESE	6	Cloudy 8 P M, passing showers
S. *Glencaird*	6 53 S	92 6	·765	·815	+ ·015	E	4	Rain squalls
S *Earl of Dunmore*	5 22 S	90 15			..	E by S	4	Cloudy 4 P M heavy rain
S *Andorina*	4 18 S	87 33				E	4	Squalls and heavy rain
S *Talavera*	2 8 S	80 53	805	·805	+ ·005	SSE	2	Rainy
S *Falconhurst*	0 19 S	77 16	809	809	+ ·009	W		Squally with rain
S.S *Rohilla*	6 4 N	91 11	759	829	—·071	ENE	4	Cloudy
S S *Kerbela*	6 25 N	80 45	765	845	—·055	NE	4	4 P M heavy rain squalls
S S *Pongola*	7 12 N	82 2	800	850	— 050	NNE	2	Occasional rain
S S *Congella*	7 32 N	83 32	906	906	+ 006	NNE?	2	Fine and clear
Barque Gulf Stream	9 13 N	89 4	825	825	—·075	ENE	5	Squalls and rain
Pulu Bras } Coast of Sumatra.						E	.	
Baros } Coast of Sumatra.						SE		
Natal } Coast of Sumatra.						E		
Port Blair	.		873	865	— 059	ENE	7	Cloudy
Camorta			898	868	?	E	5	Fine light rain during past 24 hours

Seven ships lay in south latitudes. The first six reported easterly and south-easterly winds, the force ranging from 6 on board the *Falls of Garry* in Lat. 7°54′ S. and Long. 92° E. to force 2 on board the *Talavera* in Lat. 2°8′ S. and Long 80°53′ E. The weather was squally over the whole region covered by these vessels and heavy rain was reported by the *Earl of Dunmore* and the *Andorina*. The seventh vessel was the *Falconhurst* close to the Equator in Long. 77°16′ E., and had a light westerly wind and squally rainy weather at 8 A.M. and torrents of rain later in the day. To the north of the Equator there were three ships which all reported north-easterly Trades, moderate to fresh in force, and squalls with heavy rain. The Sumatra observatories showed steady easterly and south-easterly Trade winds. The lowest pressures lay between the Equator and two degrees to the south and between Long. 77° E. and Long. 81°E.

Conditions were thus very similar on the 2nd to those reported on the 1st. Strong Trades with squalls and heavy rain were blowing on either side of the Equator, while between the Equator and Lat 2° S. there was a region of light variable winds and squally, rainy weather. The only important change was the tendency to concentration which is shown by the lie of the isobars.

December 3rd.—The chart (Pl. XXXVII) for the day showed that the tendency to concentration which had been disclosed on the 2nd had continued. The barometer had fallen over the south of the Bay and the Equatorial region to the southward, while it had risen at Singapore on the one hand and at Point de Galle on the other, and as a consequence the low pressure area over the Equator had intensified and become smaller and better defined.

The following table gives the meteorological data for this day :—

Name of Vessel.	8 A.M. Position.		Barometer			Wind.		Weather.
	Lat.	Long. E.	Barometer.	Corrected.	Variation.	Direction	Force.	
	° ′	° ′	"	"	"			
S. *Zemindar*	5 59 S	87 13	29·823	29·823	+·023	ENE	2	Heavy rain.
S. *Falls of Garry*	5 6 S	91 59	·806	·856	+·056	ESE	4	Showery.
S. *Glencaird*	4 31 S	91 40	·765	·815	+·015	E	4	Passing showers.
S. *Earl of Dunmore*	4 3 S	90 7	...	...	...	Var.	1	Cloudy. Noon, heavy rain.
S. *Andorina*	3 20 S	88 26	...	...	...	Var.	2	Cloudy. 4 P.M., heavy rain.
S *Talavera*	1 44 S	82 22	·795	·795	—·005	SW	4	Cloudy. Midnight, heavy rain.
S. *Falconhurst*	1 11 N	79 47	·810	·610	—·090	W	5	Squally with rain.
S.S *Congella*	4 24 N	80 0	·916	·856	—·044	N	4 to 2	Rainy.
S S. *Peninsular*	5 50 N	82 11*	·603	·603	—·297	Var.	2 to 3	Showery.
S.S. *Rohilla*	6 11 N	86 9	·796	·866	—·034	NE	2	Overcast. Noon, light rain.
Pulu Bras } Coast of Sumatra.	...	...	...	...	...	E	...	......
Baros } Coast of Sumatra.	...	...	...	...	...	S	...	......
Natal } Coast of Sumatra.	...	...	...	...	...	E	...	......
Port Blair	...	...	·873	·865	— ·059	ENE	5	Fine.
Camorta	...	...	·882	·852	?	NE	4	Fine.

* Noon position.

The above shows that the winds to the south of the depression had decreased in force. The *Zemindar*, the *Falls of Garry* and the *Glencaird* reported moderate easterly winds with passing showers, while the *Earl of Dunmore* and the *Andorina* which were close to or within the central area had variable light unsteady winds at 8 A.M. with heavy rain later in the day. At 4 P.M. on board the *Falls of Garry* and the *Glencaird* the trade winds were lost and the wind fell to light variable airs with heavy incessant rain. On the western margin of the central depression on the contrary the wind had undergone important changes. The *Falconhurst*, which had a light westerly wind on the previous day, now had a fresh westerly wind, and the *Talavera* which on the 2nd reported a light south-south-east wind now experienced a moderate south-west wind. These changes in direction and force are important, because they show that the circulation which was developing around the depression was assuming the form applicable to a depression in the Northern Hemisphere. The observations from ships to the northward of the depression exhibited little change, but at the Nicobars the wind had shifted from east to north-east a change which helps to indicate the concentration of the disturbance in the south. At 4 P.M. the *Falls of Garry* lost the south-east trade winds and experienced variable "puffy" breezes with heavy rain, while the *Falconhurst* had torrents of rain the whole day.

December 4th.—The chart (Pl. XXXVIII) of the 4th December exhibits a slight barometric rise over Equatorial regions, but there was no change in the position of the area of disturbed conditions which remained central over the Line. Pressure had become more uniform throughout the Bay and the sea to the southward.

The following table gives the meteorological data for this day :—

Name of Vessel.	8 A.M. Position.		Barometer.			Wind.		Weather.
	Lat.	Long. E.	Barometer.	Corrected.	Variation.	Direction.	Force.	
	° ′	° ′	"	"	"			
S. *Falls of Garry* . . .	3 35 S	91 49	29·836	29·836	+·036	Var.	1	8 P.M., continuous downpour with thunder and lightning.
S. *Zemindar* . . .	3 27 S	66 57	·823	·823	+·023	ESE	4	Squalls and heavy rain.
S. *Glencaird* . . .	3 24 S	91 37	? ·865	? ·915	+·115	E	2	Fine. 4 A.M., heavy rain
S. *Earl of Dunmore* . .	3 06 S	90 8	...	...	...	Var.	1	Cloudy.
S. *Andorina*	2 21 S	88 56	...	...	...	SSW	2	Much rain.
S. *Talavera*	1 31 S	85 13	·845	·845	+·045	Var.	6	Heavy rain.
S. S. *Cengella* . . .	1 43 N	77 36	·893	·893	—·007	NW	5	Squally.
S. *Falconhurst* . . .	2 33 N	82 5	·831	·831	—·069	NW	2	Squalls and heavy rain.
S.S. *Queen Olga* . . .	6 4 N	81 0	·789	·929	+·029	ENE	3	Cloudy. 10 P.M., showery
S. S. *Peninsular* . . .	6 5 N	86 50	·807	·807	—·093	NE	3	Cloudy. 4 A.M., rainy.
S. S. *Rohilla*	6 6 N	80 55	·767	·837	—·063	NW	2	4 P.M., cloudy.
S. S. *Virawa*	6 48 N	82 23	·834	·874	—·026	Var.	1	Fine. 8 P.M., rainy.
Pulo Bras } Coast of Sumatra	...	...	...	...	...	E	...	......
Baros } Coast of Sumatra	...	...	...	...	...	SE	...	......
Natal } Coast of Sumatra	...	...	...	...	...	S	...	......
Port Blair		...	·893	·885	—·039	ENE	3	Fine.
Camorta			·907	·877	?	NE	2	Cloudy. Moderate rain during past 24 hours.

Within the depression area the most marked feature was the heavy rainfall.

The *Falls of Garry*, the *Glencaird*, the *Peninsular*, the *Zemindar*, the *Andorina*, the *Talavera* and the *Falconhurst*, all had heavy continuous rain. On board the *Falls of Garry* and the *Glencaird* light variable airs and calms prevailed throughout the whole day with a continuous downpour of rain. The winds on the western side of the depression area had veered and were north-westerly with squalls. The south-east Trades on the south side of the depression had become lighter. The *Falls of Garry* and the *Earl of Dunmore* reported variable winds and the wind direction on board the *Andorina* in Lat. 2°21′ S. and Long. 88°56′ E. had shifted to south-south-west. This was very important in view of the general change which occurred in south latitudes on the following day. On the coast of Sumatra the wind had shifted to south at Natal and to south-east at Baros, but remained easterly at Pulu Bras (Achin Head).

December 5th.—On this day a large trough of relatively low pressure (29·85″) lay over Equatorial regions to the south of India (Pl. XXXIX). Within this trough between Longs. 88° and 92° E. and between the Line and Lat. 4° S., a small central area of depression had been developed and the barometer readings on board the *Falls of Garry* and the *Zemindar* were 0·050″ and 0·060″ respectively lower than on the preceding day.

The following table gives the meteorological data for this day :—

Name of Vessel.	8 A.M. Position.		Barometer.			Wind		Weather.
	Lat.	Long E.	Barometer.	Corrected.	Variation.	Direction	Force.	
	° ′	° ′	″					
S. *Falls of Garry* . .	2 31 S	91 42	29·786	29·786	—·014	Var.	2	
S. *Earl of Dunmore* .	2 16 S	90 14	...	...	...	NW	1	Cloudy.
S. *Glencaird* . .	2 11 S	91 38	? ·865	? ·915	+ ·115	SW	...	Passing showers
S. *Zemindar* . .	1 17 S	87 47	·763	·763	—·037	W by S	3	Hard squalls.
S. *Andorina* . . .	1 2 S	90 23	...	...	...	WSW	4	Showery.
S. *Talavera* . . .	0 48 S	88 2	·825	·825	+ ·025	WSW	5	Overcast. 4 P M squalls and heavy rain
S. S. *Congella* . .	0 16 N	75 27	? ·924	? ·924	—·026	SW	4	Overcast.
S. *Falconhurst* . .	4 04 N.	84 6	·842	·842	—·058	SW	5	Overcast. Noon, squalls and heavy rain.
S S. *Inchbarra* . .	5 45 N.	83 2	·876	·876	—·024	NE	4	Incessant rain.
S. S *Peninsular* . .	5 58 N.	92 24	·805	·805	—·095	ENE	3 to 4	Passing showers
S. S. *Vadala* . . .	6 15 N.	80 48	·818	? 858	—·042	Calm.	0	Cloudy. 9-30 P.M., heavy squalls of rain
Pulu Bras } Coast of Sumatra.	...	...	...	...	...	E	...	
Baros . } Coast of Sumatra.	...	..	...	...	...	SW	..	
Natal . } Coast of Sumatra.	...	...	...	...	...	NE	..	
Port Blair . . .	...	...	·876	·868	—·056	ENE	5	Cloudy.
Camorta . . .	...	...	·898	·868	?	NE	3	Cloudy.

The lowest pressures were thus between Lat. 2°31′ S. and Lat. 1°17′ S. The wind force was not very high except during the squalls which were frequent. The weather was overcast and heavy rain was reported all around the depression area. The most important feature was, however, the change in the wind direction. On the 4th it was noticed

that on board the *Andorina* in Lat. 2°21′S. the wind had shifted to south-south-west and the circulation was consequently assuming a direction appropriate to a storm in the Northern Hemisphere. On the 5th the observations showed that the wind had gone round to the westward on board all the vessels between the Equator and Lat. 4° S. With high pressures in the far south and low pressures in Lat. 2°S. the appropriate direction of the wind would be east or south-east, but in the present instance the observations exhibit westerly winds prevailing on the south side of a low pressure area in southern latitudes. At Natal the winds had backed to north-east and at Baros had veered to south-west, while at Pulu Bras it remained easterly. In the Bay Islands the barometer was falling.

December 6th.—On December 6th the chart (Pl. XL) showed that a considerable concentration of the depression had taken place and that a trifling northward movement had been developed. The lowest pressure 29·736″ was reported by the *Falls* of *Garry* in Lat 0° 18′S. and Long. 92° 6′E.

The following table gives the meteorological data for this day :—

Name of Vessel.	8 A.M. Position.		Barometer			Wind		Weather.
	Lat.	Long E.	Barometer	Corrected	Variation	Direction	Force	
	° ′	° ′	″	″	″			
S. *Earl of Dunmore*	0 35 S	90 30	.			W by N	..	Hard squalls
S *Falls of Garry*	0 18 S	92 6	29·736	29·736	— ·064	WNW	5	Heavy rain
S. *Glencaird*	0 21 N	92 19	? 865	? 915	+ ·050	WNW	6	Small passing showers
S *Talavera*	1 20 N	90 39	805	·805	— ·095	NNW	6	Cloudy Noon, showery
S. *Andorina*	1 57 N.	92 17	..			NW	6	Squally with rain
S *Zemindar*	2 1 N.	88 42	813	813	— ·087	WNW	6	Occasional squalls
S *Falconhurst*	5 15 N.	86 05	829	829	— ·071	WNW	6	Squally with rain
S.S *Inchbarra*	5 42 N.	86 19	847	847	— ·053	W	4	Overcast and moderate sea 4 P.M., incessant rain
S.S. *Clitus*	5 47 N.	94 40	·872	·922	+ ·022	S	4	Overcast 8 P.M., showery
Pulu Bras } Coast of Sumatra	...				.	W	.	
Baros } Coast of Sumatra	...		..			SW		
Natal } Coast of Sumatra			.		.	NNE		
Port Blair	...		·881	873	— ·051	NNE	5	Cloudy
Camorta	.	.	902	872	?	NE	2	Cloudy

All the ships near the central area of depression reported north-westerly or west-north-westerly winds with a force of 5 to 6 and occasional squalls. Rain was reported from all the ships and heavy rain from the *Falls of Garry* which was near the centre of disturbance. The *Earl of Dunmore* experienced hard westerly squalls and heavy rain all day, and the *Falconhurst* had continuous heavy rain. On board the *Falls of Garry* the barometer had fallen 0·050″ while, on the contrary, on board the *Zemindar* which was being left behind by the disturbance there had been a brisk recovery. The barometer was rising a little at the Bay Islands, but the wind had drawn from east-north-east into north north-east at Port Blair.

December 7th.—The chart of December 7th (Pl. XLI) showed that the northward movement of the depression had continued and that the centre was in about Lat. 3° N. and Long. 92°30′ E., and that the cyclonic circulation was more complete and definite than hitherto.

The following table gives the meteorological data for this day:—

Name of Vessel.	8 A.M. Position.		Barometer.			Wind		Weather.
	Lat. N.	Long E.	Barometer.	Corrected	Variation.	Direction.	Force.	
	° ′	° ′	″	″	″			
S. *Earl of Dunmore*	2 14	90 41	...	...	...	W	2	Cloudy. 4 P.M., heavy rain.
S. *Falls of Garry*	2 55	92 18	29·736	29·736	—·164	WNW	6	Heavy squalls.
S. *Glencaird*	3 2	92 52	?845	?895	—·005	WNW	3	Heavy rain
S. *Talavera*	3 8	92 36	·785	·785	—·115	W	4	Frequent squalls of wind and rain.
S. *Andorina*	3 57	92 39	...	...	..	WNW	2	Rainy.
S. *Zemindar*	4 2	90 12	·803	·803	—·097	NNW	2	Frequent heavy showers.
S. *Falconhurst*	5 30	86 55	·818	·818	—·082	NE	1	Overcast. 4 A.M., steady rain.
S.S. *Clitus*	5 40	90 22	·882	·932	+·032	NE	2 to 4	Very heavy rain.
S.S. *Inchbarra*	5 53	89 54	·817	·817	—·083	Var.	5	Passing showers.
Pulu Bras (Coast of Sumatra)	...	...	...	...	...	W	...	
Baros (Coast of Sumatra)	...	...	..	...	...	SW	...	
Natal (Coast of Sumatra)	...	...	...	...	...	NNW	...	
Port Blair	...	...	·892	·882	—·042	NNE	7	Cloudy.
Camorta	..	...	·906	·876	?	ENE	2	Cloudy. Light rain during past 24 hours.

The lowest pressure, 29·736″, which is the same as on the preceding day was again reported from the *Falls of Garry*. This vessel lay in Lat. 2° 55′ N. and Long. 92° 18′E., and experienced a strong (force 6) west-north-west wind and hard squalls. The nearest ship to this was the *Talavera* which was in Lat. 3°8′N. and Long. 92°36′E., with a barometer reading corrected of 29·785,″ a moderate westerly wind and frequent squalls of wind and rain. To the west of the central area of depression were the *Clitus* with a north-east wind and very heavy rain; the *Falconhurst* with a north-east wind and steady rain all the morning, and the *Zemindar* with a north-north-west wind and frequent heavy showers. There was no information from the region to the east of the disturbance. Rain had commenced at the Nicobars where the wind had shifted from north-east to east-north-east.

December 8th.—The chart (Pl. XLII) showed that the storm had not maintained quite the same intensity that it possessed on the preceding day, the lowest pressure being 29·766″ reported on the *Falls of Garry* in Lat. 4°18′ N. and Long. 92°4′ E., while on the 7th on board the same ship the lowest pressure was 29·736″. The storm had moved very slightly northward, and the centre lay in about Lat. 4° N. and Long. 93°E.

The following table gives the meteorological data for this day :—

NAME OF VESSEL.	8 A.M. POSITION.		BAROMETER.			WIND.		WEATHER.
	Lat. N.	Long. E.	Barometer.	Corrected.	Variation.	Direction.	Force.	
	° ′	° ′	"	"	"			
S. *Earl of Dunmore* .	3 5	90 50	...	...	...	NNE	2	Cloudy. 4 A.M., hard squalls.
S. *Falls of Garry* . .	4 18	92 4	29·766	29·766	—·134	N	5	Light rain.
S. *Talavera* . .	4 40	92 40	·805	·805	—·095	NNE	5	Overcast. Noon, squalls and rain.
S. *Glencaird* . .	4 44	92 18	·755	·805	—·095	N	5	Heavy squalls and torrents of rain.
S. *Zemindar* . .	5 3	89 53	·863	·863	—·037	NE by E	3	Occasional showers.
S. *Falconhurst* . .	5 5	88 0	·812	·812	—·088	NE by N	4	Fine.
S. *Andorina* . .	5 14	92 53	...	...	...	N	2	Heavily overcast.
S S. *Arratoon Apcar* .	Pen	ang.	·824	...	...	...	...	8 P.M. showery.
S.S. *Purnea* . .	Pen	ang.	·779	...	...	...	...	8 P.M., cloudy.
S.S. *Clitus* . . .	5 38	86 10	922	·972	+·072	N	5	Cloudy. Noon, continuous rain
S.S. *Inchbarra* . .	5 44	92 52	·789	·789	—·111	NE by N	5	Passing rain squalls, and moderate sea.
Port Blair . . .	...	...	·917	·909	—·015	NNE	7	Cloudy.
Camorta . . .	...	...	·885	·855	?	N	0	Overcast.
Pulu Bras (Coast of Sumatra)	...	...	...	...	...	SE	...	
Baros . (Coast of Sumatra)	...	...	...	...	...	ESE	...	
Natal . (Coast of Sumatra)	...	...	...	...	...	E	...	

All the vessels in the neighbourhood of the disturbance lay to the northward or westward of the central area of depression and hence the cyclonic circulation was far from complete. At Camorta the wind had shifted to north and the barometer fallen 0·021". The *Earl of Dunmore* in Lat. 3°5′ N. Long. 90° 50′ E. had a north-north-east wind and hard squalls; the *Falls of Garry*, the *Glencaird* and the *Andorina*, all to the west or in front of the disturbance had northerly winds, overcast skies and squally weather, the *Glencaird* also reporting torrents of rain. The only observations to the east of the centre were those recorded on the west coast of Sumatra. Thus Pulu Bras (Achin Head) reported a south-east wind; Baros an east-south-east wind and Natal an east wind. It is obvious on this day that, with the exception of on board the *Glencaird*, the rainfall had been lighter and the storm appears to have grown less intense.

December 9th.—On the 9th the chart (Pl. XLIII) showed a further northward movement of the storm. The central area of depression was apparently close to, and a little to the northward of the *Talavera*, and was hence in about Lat. 5° 15′ N. and Long. 93° E. The intensity was unchanged, the barometer on the *Talavera* reading 29·765" while the lowest reading on the previous day, on board the *Falls of Garry*, was 29·766". The *Falls of Garry* had passed to the west of the depression and the barometer on board was rising briskly. From 4 P.M. to midnight on board this ship, and also on the *Glencaird* a heavy westerly gale was experienced with torrents of rain and a high confused sea. It is remarkable

how sharply defined was the storm area, as both at Port Blair and Camorta the barometer had risen and the weather was not noticeably affected, though the *Gulf Stream* in Lat. 11° 33'N. and Long. 91° 29'E. reported a heavy leaden sky.

The following table gives the meteorological data for the day :—

Name of Vessel.	8 A.M. Position.		Barometer.			Wind.		Weather.
	Lat. N.	Long E.	Barometer.	Corrected	Variation.	Direction	Force.	
	° ′	° ′	"	"	"			
S. Earl of Dunmore .	3 37	91 19	...	...	...	Var.	1 to 0	Heavy rain.
S. Talavera . . .	4 52	92 50	29·765	29·765	—·135	NW	8	4 A.M., showery.
S. Glencaird . . .	5 2	90 55	755	29·805	—·095	NNW	5	Steady rain.
S. Falconhurst . .	5 8	90 6	·862	·862	—·038	N	2	Overcast. 8 P.M., heavy squalls and heavy rain.
S. Falls of Garry . .	5 14	91 48	·786	·836	—·064	N	2	Heavy continuous rain.
S.S Inchbarra . .	5 52	95 26	·824	·824	—·076	E	5	Showery.
S. Zemindar . . .	6 4	87 52	·943	·943	+·043	NE by N	4	Overcast. 8 P.M., frequent showers.
S. Andorina . . .	6 53	91 28	...	...	...	NE by N	6	Gloomy. 4 P.M., heavy squalls.
Port Blair . . .	...	...	·947	·939	+·015	NNE	10	Coudy.
Camorta . . .	...	..	·918	·888	?	NNE	1	Overcast. Light rain during past 24 hours.
Pulu Bras (Coast of Sumatra)	...	...	...	...	...	E		
Barcs (Coast of Sumatra)	...	...	...	...	...	ESE		
Natal (Coast of Sumatra)	...	..	...	...	...	E		

The cyclonic circulation was better defined than on the 8th, the vessels involved in the disturbance being more scattered. The *Talavera* close to the centre of the disturbance had a north-west fresh gale and "dirty" weather, and later in the day a strong westerly gale and heavy rain; the *Falls of Garry*, a little to the west of the depression, a light northerly wind and heavy continuous rain; the *Glencaird* in Lat. 5° 2′ N. and Long. 90° 55′E. had a fresh north-north-west wind and steady rain ; the *Inchbarra* in Lat. 5° 52′ N. and Long. 95° 26′ E. had a fresh easterly wind and showers, and the *Falconhurst* had during the day a fresh westerly gale with heavy rain. At Achin Head and along the west coast of Sumatra easterly winds were reported.

December 10th—The chart of December 10th (Pl. XLIV) shows apparently that the storm had commenced to move slightly north-westward or north-north-westward, though the observations are not altogether reliable. The centre of the depression was apparently close to the *Glencaird* and the *Falconhurst* which were in Lat. 5° 39′ N. and Long. 91° 5′ E. and Lat. 5° 51′ N. and Long. 91° 13′ E. respectively. The latter vessel experienced a hard gale and torrents of rain during the whole of the 10th and until 4 A.M. on the 11th and the former a hurricane from west to west-south-west during the whole day. The storm had become more intense and pressure at the centre was 0·10" lower than on the preceding day. The wind directions on board the *Andorina* on this and the following

day are almost certainly incorrect and should be reversed. This ship had a strong to heavy gale all day with a high confused sea.

The following table gives the meteorological data for this day :—

Name of Vessel.	8 A.M. Position.		Barometer.			Wind.		Weather.
	Lat. N.	Long. E.	Barometer	Corrected.	Variation.	Direction.	Force.	
	° ′	° ′	″	″	″			
S. Earl of Dunmore	4 07	93 18	...	...	...	SW	2	Cloudy.
S. Falls of Garry	4 56	92 57	29·686	29·736	—·164	W by S	7	4 P.M., passing showers.
S.S. Inchbarra	5 09	98 01	·916	·916	+·016	ESE	6	Incessant rain with moderate head sea.
S. Talavera	5 19	92 33	·765	·765	—·135	W	8	4 P.M., cloudy
S. Glencaird	5 39	91 05	·605	·655	—·245	WSW	7	High confused sea. 10 A.M. terrific squalls.
S. Falconhurst	5 51	91 13	·677	677	—·223	W	8	Heavy rain.
S. Zemindar	7 48	88 26	·893	·893	—·007	NNW	5	Squally.
S. Andorina	8 03	92 42	...	...	...	NNW	9	High sea. 4 A.M., heavy squalls
S.S. Purnea	11 54	97 03	·895	·895	—·030	E	2	Fine.
Barque Gulf Stream	12 45	89 53	·915	·915	—·010	N by E	3	Fine.
S.S. Pentakota	13 46	96 42	·959	·959	+·034	ENE	2	Fine and smooth sea.
Port Blair	...	...	·916	·908	—·016	NNE	13	Overcast.
Camorta	...	...	·884	·854	?	ESE	0	Overcast Heavy rain during past 24 hours.
Pulu Bras } Coast of Sumatra.	...	...	...	...	...	SE	...	
Baros } Coast of Sumatra.	...	...	...	...	...	SE	...	
Natal } Coast of Sumatra.	...	...	...	...	...	E	...	

The *Falconhurst* and *Glencaird* both lay immediately to the south of the centre of the depression and experienced a moderate to fresh westerly and west-south-westerly gale with a high confused sea, terrific squalls and heavy rain. The *Talavera* lay a little further to the southward and had a strong westerly gale and heavy rain all day, and the *Falls of Garry* lay to the south-east and had a moderate west by south gale and the weather was moderating. The *Inchbarra* in the Malacca Strait had a strong east-south-east wind and incessant rain, Achin Head had a south-east wind and Camorta an east-south-east wind and heavy rain. The *Zemindar* to the north-west of the disturbance had a fresh north-north-west wind with squalls, and the *Andorina* near the Nicobars reported a hard north-north-west gale with a high sea and heavy squalls.

December 11th.—The chart (Pl. XLV) shows that the storm centre had continued to move north-north-westward and the area of greatest barometric depression lay between the *Zemindar* and the *Glencaird* and was probably in about Lat. 8° 50′ N. and Long. 90° 10′E.

Pressure had fallen slightly within the storm area and the lowest barometric reading reported was about 0·03″ lower than the lowest on the 10th.

The following table gives the meteorological data for this day :—

Name of Vessel.	8 A.M. Position.			Barometer.		Wind.		Weather.
	Lat. N.	Long. E.	Barometer.	Corrected.	Variation.	Direction.	Force.	
	° ′	° ′	″	″	″			
S. *Earl of Dunmore*	4 49	93 43	...	...	...	SSE	2	Clear. 8 P.M., heavy rain.
S. *Falconhurst*	6 16	91 55	29·716	29·716	—·184	SSW	4	Passing squalls with rain.
S. *Falls of Garry*	6 58	92 28	·836	29·886	—·014	SSE	5	Heavy showers.
S. *Talavera*	7 09	92 17	..	...	...	SSW	6	Heavy squalls and blinding rain
S. *Glencaird*	8 22	91 27	·675	·725	—·175	SSE	6	Sharp squalls and heavy rain.
S *Zemindar*	8 29	89 27	·623	·623	—·277	N by W	...	Terrific squalls and heavy rain with heavy confused sea.
S. *Andorina*	9 32	93 18	...	...	...	E?	9	Every appearance of a cyclone. Midnight, heavy squalls
S S. *Pentakota*	10 12	97 17	·869	·869	—·056	ENE	4	Passing clouds and moderate sea
S.S. *Saint Hubert*	11 21	84 09	·753	·863	—·058	NE	4	Light showers.
Barque Gulf Stream	13 50	88 50	·856	·856	—·094	NE	5	Cloudy. Midnight heavy drops of rain.
S S. *Chelydra*	15 22	92 32	898	·888	—·062	ENE	4	Fine.
Port Blair	...	..	·818	·810	—·114	ESE	9	Overcast.
Camorta	...	...	·829	799	?	E	0	Cloudy Heavy rain during past 24 hours.

A fairly well-defined cyclonic circulation prevailed around the low pressure area, but there is no information available for the south-west quadrant of the storm. The *Zemindar* lay to the west of the central area of depression and reported a north by west wind, terrific squalls, heavy rain and a high confused sea. At 8 A.M. a terrific squall struck the vessel; at 8-30 A.M. the wind shifted suddenly from north to west with heavy rain and blew with hurricane force from south-west. It then veered again to west, blowing and raining very heavily. At 11 A.M. the weather began to moderate. The *Glencaird* lay on the opposite side of the storm area and experienced a south-south-east strong wind sharp squalls and heavy rain. To the south-east of the storm were the *Falls of Garry*, the *Falcon hurst* and the *Talavera*; all had south winds, heavy squalls and blinding rain The *Andorina* to the east-north-east of the depression had an easterly hard gale and reported "every appearance of a cyclone." At Port Blair the barometer had fallen nearly 0·10″ and the wind had veered to east-south-east. The observations recorded on the ships lying on the outer limits of the storm show a fairly regular cyclonic circulation.

December 12th.—The chart of the 12th (Pl XLVI) apparently shows that the storm had moved northward through about a degree and a half and lay in about Lat. 10° N. and

Long. 90° 10' or 15'E. The intensity of the storm was probably slightly less than on the 11th, the lowest pressure reported being 29·665" on board the *Talavera*. The cyclonic circulation was ill-defined and the force of the wind had decreased.

The following table gives the meteorological data recorded on this day :—

Name of Vessel.	8 A.M. Position.		Barometer.			Wind.		Weather.
	Lat. N.	Long. E.	Barometer	Corrected.	Variation.	Direction.	Force.	
	° ′	° ′	"	"	"			
S.S. *Angers* . . .	6 05	94 08	...	...	...	ESE	2	
S. *Earl of Dunmore* . .	6 08	93 12	...	...	...	SE	2	Fine.
S. *Falconhurst* . .	9 25	92 10	29·713	29·713	—·187	SE	5	Fine. 4 A.M., passing showers.
S. *Zemindar* . .	9 55	89 46	·783	·783	—·117	SW	4	Frequent rain squalls.
S. *Talavera* . . .	10 13	91 50	·665	·665	—·235	SSE	7	Heavy squalls and blinding rain.
S. *Falls of Garry* . .	10 49	91 44	·736	·786	—·114	SE	5	Passing showers.
S. *Glencaird* . .	11 46	91 17	·745	·795	—·130	SE	6	Ditto.
S.S. *Chelydra* . .	13 09	94 18	·858	...	...	ESE	5	Squally, with rain and moderate sea.
S. *Andorina* . .	13 15	93 22	...	...	...	SE	7	Heavy squalls.
Barque Gulf Stream .	14 19	88 11	·801	·801	—·149	NE by N	6	Rainy. 8 P.M., heavy gale with violent squalls.
Port Blair . . .	...	...	·795	·787	—·137	SSE	20	Overcast. Heavy rain during past 24 hours.
Camorta . . .	...	...	·874	·844	?	SE	6	Cloudy. Heavy rain during past 24 hours.

The ship nearest to the centre of the storm was the *Talavera* with a south-south-east moderate gale, heavy squalls and blinding rain. The *Falconhurst*, the *Falls of Garry*, the *Andorina* and the *Glencaird* all lay to the eastward of the centre and reported south-east strong winds or moderate gales all day with squalls and showers. At Port Blair the barometer was still falling, the wind had gone round to south-south-east and was blowing at the rate of 20 miles per hour while heavy rain had fallen both there and at Camorta. The Barque *Gulf Stream* which at 8 A.M. lay in Lat. 14° 19' N. and Long. 88° 11' E. and was proceeding southward ran into a heavy north-east gale with violent squalls at 8 P.M. with a continuous downpour of rain.

December 13th.—The storm had moved more quickly than hitherto and the centre lay in about Lat. 13° 40' N and Long. 90° 10'E. (Pl XLVII). The storm was beginning to fill up and the lowest pressure reported was 29·725" on the *Talavera*. The rainfall was apparently less heavy generally, and the wind was going down. The *Glencaird* reported that the weather was clearing. The barometer reading on board the *Gulf Stream* has been rejected as it is hardly possible that pressure could have fallen

as low as 29·572″ in the position given. Rejecting this reading and adopting a reading of 29·725″ on board the *Talavera*, the chart shows a further northward movement of the storm, the centre of which lay apparently in about Lat. 13° 40′ N. and Long. 90° 10′ or 15′ E. The cyclonic circulation was again ill-defined.

The following gives the meteorological data for this day:—

Name of Vessel.	8 A.M. Position.		Barometer.			Wind.		Weather
	Lat. N.	Long. E.	Barometer.	Corrected.	Variation.	Direction.	Force.	
	° ′	° ′	″	″	″			
S. *Earl of Dunmore*	73 7	92 17	...	...	...	SE	2	Fine.
S. *Zemindar*	11 58	91 05	29·903	29·903?	—·022	SE by S	3	Fine. 4 A.M., squally
S. *Falconhurst*	13 41	92 32	·817	·817	—·113	SE	4	Fine. 4 A.M., squally with rain.
S. *Talavera*	13 50	90 59	·825	?·725	—·200	ESE	6	Fine. 4 P.M., heavy rain.
Barque Gulf Stream	14 00	87 50	·572	?·572	—·378	Var.	1	4 A.M., heavy pouring rain and heavy peals of thunder and lightning.
S. *Falls of Garry*	15 22	92 5	·786	·836	—·114	ESE	6	Overcast. 4 P.M., dirty, rainy.
S. *Glencaird*	15 35	92 00	·765	·815	—·135	E	6	Clearing. 4 A.M., heavy squalls
S. *Andorina*	16 32	93 54	...	...	...	SE	9	Terrific squalls
S S. *Africa*	16 34	93 1	·904	30·024	+·064	E	5	Fine and fresh sea; midnight, squally and steady rain.
S.S. *Bhundara*	17 00	86 00	·701	·801	—·199	NE	4	Passing rain squall.
S.S *Saint Hubert*	18 35	87 14	746	·856	—·144	NE by E	6	Misty. 4 A.M., squally.
S.S. *Chyebassa*	19 0	84 40	840	·910	—·090	NNE	6	Overcast.
S S. *Malda*	19 02	90 36	·881	·981	—·019	E	5	Drizzling
S. *Morven*	20 42	89 17	30·025	·955	—·045	NE	4	Drizzling rain.
Port Blair	...	...	·869	·861	—·063	SSE	20	Cloudy. Light showers during past 24 hours.
Camorta	...	...	·917	·887	?	E	6	Fine.

The *Talavera* was nearest to the centre of the disturbance and had fine weather. The *Falconhurst* to the east had also fine weather and a moderate south-east wind; the *Falls of Garry* and the *Glencaird* had strong easterly winds and the *Andorina* still further to the north-eastward had a south-east hard gale with terrific squalls, but subsequently the weather moderated. The *Gulf Stream* which on the previous evening had experienced a violent gale now reported light variable winds. At 4 A.M. she had passed through heavy pouring rain. At Port Blair the wind was still blowing with a force of 20 miles per hour from south-south-east. Strong north-easterly winds were blowing to the north-west of the storm, and the improvement in the weather appeared to be spreading from the centre to the exterior of the storm area.

December 14th.—The chart (Pl XLVIII) shows that pressure had continued to increase and the depression to fill up. The centre of the disturbance had travelled quickly northward and lay in about Lat. 18° 10′ N. and Long. 91° E., and the cyclonic circulation around the centre was ill-defined.

The following table gives the meteorological data recorded on this day:—

Name of Vessel	8 A.M. Position.		Barometer.			Wind.		Weather.
	Lat. N.	Long. E.	Barometer.	Corrected.	Variation.	Direction	Force.	
	° ′	° ′	″	″	″			
S.S. *Bhundara* . .	13 50	84 15	29·848	29·948	—·027	S	2	Noon, passing clouds.
S. *Zemindar* . .	15 09	91 39	30·023	30·023	+·073	SE	3	Fine.
Barque Gulf Stream .	16 04	90 47	29·927	29·927	—·023	S	6	Squally. Midnight, thunder and lightning and blinding rain.
S. *Talavera* . . .	17 06	92 22	·965	·965	+·015	E	5	Cloudy. Midnight, drizzling rain.
S. *Falconhurst* . .	17 13	91 51	·931	·931	—·019	E	5	Squally with rain.
S. *Andorina* . . .	17 40	90 36	...	...	...	N	2	Heavy clouds. 4 P.M. heavy squalls.
S. *Glencaird* . .	18 37	91 46	·775	·825	—·150	ENE	8	Drizzling rain.
S. *Falls of Garry* . .	18 40	91 37	·736	·886	—·089	NE	6	Passing showers.
S.S. *Nowshera* . .	18 44	87 01	·828	·948	—·032	Var.	4	4 P.M. squally.
S.S. *Africa* . . .	19 43	89 43	·966	30·086	+·086	ENE	6	Thick rain and strong sea. 4 A.M. very heavy squall.
S.S. *Loodiana* . .	20 22	87 47	·970	·970	—·030	E	4	Occasional showers and high sea.
Port Blair . . .	...	...	965	·957	+·033	SSE	15	Cloudy.
Camorta . . .	...	...	·991	·961	?		6	Fine.

The lowest pressure reported was 29·825″ which was exactly 0·10″ higher than the lowest pressure recorded on the preceding day. At Port Blair the barometer had also risen nearly 0.10″, and the velocity of the south-east wind had decreased from 20 to 15 miles per hour. The *Glencaird* which lay nearest to the central area of depression reported an east-north-east fresh gale, but elsewhere the winds were only moderate to strong.

December 15th.—The chart (Pl. XLIX) showed that the intensity of the depression was unchanged, but the barometer was rising generally and the disturbance was obviously filling up. The northward movement had continued, and the centre lay in about Lat. 20° 30′ N. and Long. 90° E.

The following table gives the meteorological data for this day:—

Name of Vessel.	8 A.M. Position.		Barometer.			Wind.		Weather.
	Lat. N.	Long. E.	Barometer.	Corrected	Variation.	Direction.	Force.	
	° ′	° ′	″	″	″			
S.S. *Nowshera* . .	16 10	85 49	29·891	30·011	+·031	N	4	
S.S. *Loodiana* . .	17 36	86 44	·949	29·949	—·051	N	5	Passing clouds and moderate sea.
S.S. *Choysang* . .	17 44	90 52	·977	·927	—·048	SSE	4	
S. *Zemindar* . .	17 55	91 40	·973	·973	—·007	SE	5	Cloudy. 4 P.M. occasional light showers.
Barque Gulf Stream .	19 5	90 37	·962	·962	—·038	SE	6	Rainy.
S. *Talavera* . . .	19 46	91 18	·965	·965	—·035	SE	5	Cloudy, 4 A.M. heavy rain.
S. *Falconhurst* .	20 24	91 06	30·044	30·044	+·044	SE	...	Clearing, 4 A.M. heavy rain.

Name of Vessel.	8 A.M. Position		Barometer.			Wind		Weather.
	Lat. N.	Long. E.	Barometer.	Corrected	Variation.	Direction.	Force	
	° ′	° ′	"	"	"			
S.S. *Chyebassa*	Saugor	Island	·920	29·990	—·010	N	6	Light rain.
S. *Falls of Garry*	20 31	90 10	·786	29·836	—·164	SE	2	Drizzling
S. *Glencaird*	20 33	90 12	·785	·835	—·165	SE	4	Clear. Midnight, small rain.
S *Andorina*	20 34	90 21	...	...	...	SE	4	Cloudy. 8 P.M., rainy.
Eastern Channel	...	...	30·087	...	...	NNE	4	Overcast and moderate south-east swell.
Port Blair	...	...	·979	·971	+·047	ESE	9	Cloudy.
Camorta	..	...	30·001	·971	?	NE	5	Cloudy

There was nothing particularly worthy of note in the observations on this day. The weather was more cloudy and unsettled than usual and an irregular cyclonic circulation existed.

The force of the wind was moderate to strong.

December 16th.—On this day the depression practically disappeared (Pl. L). Pressure over Bengal was high and steady, the further progress of the storm northward was barred and the centre filled up without moving.

The following table gives the meteorological data for this day:—

Name of Vessel.	8 A.M. Position.		Barometer.			Wind.		Weather.
	Lat. N.	Long. E.	Barometer.	Corrected.	Variation.	Direction	Force.	
	° ′	° ′	"	"	"			
SS. *Sultan*	16 50	86 1	...	...	...	N	...	Heavy head sea. Noon, stormy.
S. *Zemindar*	19 24	90 19	30·003	30·003	+·003	SE	3	Occasional light showers.
SS. *Lindula*	19 32	89 57	29·889	29·889	—·111	Calm	0	Squally.
S. *Talavera*	20 38	88 57	30·045	30·045	+·045	E	5	Cloudy.
Barque Gulf Stream	20 43	88 19	·037	·037	+·037	N	6	Heavy rain.
S. *Andorina*	20 58	88 32	...	...	...	ENE	4	Overcast.
S. *Falconhurst*	21 02	88 34	·044	30·044	+·044	NE	5	Thick weather.
Eastern Channel	...	...	30·111	...	..	N	5	Cloudy and slight south swell.
Port Blair	...	...	29·969	29·961	+·037	NNE	6	Cloudy.
Camorta	...	...	·998	·968	?	E	3	Overcast.

The winds remained strong and there was a good deal of rain with squally weather, but the disturbance as a definite depression ceased to exist on this day.

Conclusions.

So much attention has been devoted to the discussion of cyclonic storms in the Bay, that unless a particular disturbance presents peculiar and individual features it is seldom worth while at the present time to do more than to briefly record the occurrence, path and intensity of any fresh storm. In the present instance there appeared to the writer

to be sufficient individuality about the storm to justify the short discussion given above. The particular interest which attaches to the storm is the evidence which it supplies of the possibility of a storm forming within equatorial regions and the record of the wind changes which occur when a storm passes from these very low latitudes into the higher latitudes of the Tropics.

As regards the initiation of the storm, the charts of the first three days of December show that the south-east Trades were blowing as far north as Lat. 4° S. On the 1st the weather was fine, but on the 2nd squalls commenced, and on the 3rd, when the Trades began to take off in strength, rain commenced to fall heavily. During this period a trough of low pressure lay along the equator, and it is perfectly obvious that the doldrums and the meeting of the Trades existed directly over the equator. This condition from the point of view adopted by Professors Ferrel and Davis is probably of importance as evidence with regard to the question of temperature distribution at this time. Temperature observations were not included in the observations recorded in the logs from which the charts were constructed, so that there is no means of determining from direct observation whether at the sea surface there was any disturbance of the normal temperature distribution. This is of relatively little importance if, as Ferrel holds, and as the writer has attempted to show in the course of an investigation into the cyclones of the Arabian Sea, "the complete temperature conditions of a cyclone rarely extend to the earth's surface." The thermometric observations then, even if available would possibly not have shown any marked temperature disturbance over the region within which the storm subsequently appeared, and the circumstantial evidence afforded by the winds and the pressure distribution may probably be accepted as a safer guide.

The normals of latitude for pressure and temperature for January are as follows :—

	Pressure.	Temperature.
Latitude 10° N.	29·858	78°·62
„ 5° N.	29·842	79°·88
„ 0°	29·819	81°·14
„ 5° S.	29·807	81°·68
„ 10° S.	29·819	82°·22
„ 15° S.	29·850	80°·96

These figures show that, judged by pressure, the doldrums should lie in January over about Lat. 5° S., and, estimated from temperature, still further to the southward, so that even though the period under discussion is about six weeks earlier than the period to which the above values of pressure and of temperature apply, the fact of the position of the trough of lowest pressure over the equator and of the northward extension of the south-east Trades might be adduced as evidence of the abnormal temperature conditions on which, according to the theory of Professor Ferrel, it is presumed the first initiation of the storm depended.

It is not of course suggested that this reasoning affords evidence of the presence of the local temperature inequality on which it is assumed the initiation of a storm depends, but it shows that temperature conditions were such that the equatorial band of calms was removed to an abnormally northerly position and that conditions for convectional overturning were present in a marked degree over the area within which the storm subsequently developed.

The conditions on the 4th were very interesting. The south-east Trades were begin-

ning to fall off, and variable breezes were reported by the *Falls of Garry*, the *Earl of Dunmore* and the *Talavera*, but the Trades were still blowing up to about Latitude 3° 30′S. as shown by the observations on board the *Zemindar* and the *Glencaird*. At the same time on the north-western side of the low pressure area we have the *Peninsula* with a north-east wind and the *Congella* and the *Falconhurst* with north-west winds. As on this day the lowest pressures lay over the Line, it would appear that to the northward of the depression area the circulation appropriate to the northern, and to the southward, the circulation appropriate to the southern, hemisphere, prevailed. Seemingly the former was the more potent, and on the 5th the south-east trades had wholly disappeared.

On the 5th the depression began to assume a definite shape. The barometer had fallen briskly over the equator between Longs. 88° and 92° E. while it had been steady in surrounding regions and an irregularly shaped area of depression was formed within which during the succeeding 24 hours the central area appeared or was developed. On the morning of the 6th a well-marked central area of depression was shown over the Line towards which strong north-west winds were blowing. There were no observations recorded to the east of the disturbance, but apparently we possess on this day an illustration of the conditions contemplated by Professors Ferrel and Davis in the extracts quoted at the commencement, and by following out the reasoning adopted in these quotations, we should arrive at the following sequence of events. A local temperature inequality had produced within the cloud region a temporary temperature disturbance over the equator, and a column of ascending air was started within this region. Hence pressure at the sea surface was reduced and a surface flow of air towards the area of diminished pressure was produced with subsequent ascensional movements and heavy precipitation. But the force depending on cos ψ vanishes in this position, and hence we have a radial inflow instead of a spiral whirl, and a moderate wind velocity in place of the storm winds, which would otherwise have been associated with the barometric gradients shown on the chart (Pl. XL). Had the storm, or rather disturbance, remained stationary over the equator, it would, according to the theory, have followed, that the temperature and pressure inequalities on which its initiation had depended would have disappeared under the influence of the radial inflow of surrounding air, but, after 8 A.M. on the 6th, a northward movement was developed within the depression area, which carried it as far as Lat 4° N. by 8 A.M. on the 7th. In this position the convectional whirl was apparently far enough from the equator to give, quoting Professor Davis, the deflecting force due to the earth's rotation an effective value, so that though radial winds were still reported close to the storm, gyratory motions around the centre were developed at a distance of about 4° from the centre. As the disturbance moved more and more northward the circular component of the wind's motion became more and more pronounced, and, with it, increased the strength of the wind and the general intensity of the storm, so that instead of the forces of 5 and 6, which were the characteristics of the radial inflow of equatorial regions, forces of 9 and 10 were the characteristics of the gyratory circulation of the higher latitudes. The figure on Pl. LII. shows the wind directions recorded within 4° of the central area of disturbance on three occasions. On the first occasion *viz.*, the 6th December, the centre lay over the equator, and the wind directions exhibit an almost radial inflow, the average angle of incurvature which a line drawn from the place of observation in the direction from which winds are advancing made with a line

joining the place of observation with the centre of disturbance was as large as 150°: on the second occasion the measurements were made when the centre lay over Lat. 5° N., and in this position the angle had decreased to 125°, and when the centre had reached Lat. 9° N. the angle had still further decreased and become about 119°. These figures and still more the diagram on Pl. LII show very clearly the increasing effective value of the force depending on cos ψ and exhibit the gradual change from a radial inflow at the equator to a spiral inflow in higher latitudes.

Having now discussed in slight detail the foregoing observations, especially as they appear connected with the theory of cyclone formation, as laid down by Professors Ferrel and Davis, we will briefly review them from the point of view of the whole disturbance arising from the processes of evaporation and subsequent condensation.

On the first three days of December the charts exhibited a typical illustration of the ordinary meteorological conditions which theory assigns to the Belt of Calms. An area of continuous low barometer lay over the equator, on either side of which the two trade wind currents blew freshly, while, within the area itself, the surface winds were very light and variable. The weather was fine generally, but daily at 4 P.M., just after the diurnal period of greatest evaporation, heavy precipitation of rain took place. The charts for these days show, then, a more or less enclosed area within which the weather was fine, and constant evaporation was proceeding with apparently no horizontal outlet for the accumulating aqueous vapour. On the 3rd December the south-east trades seemingly began to take off, but the observations on this day show that nearly all the ships in southern latitudes had entered or were close to the enclosed area of light and unsteady winds and low barometer. The sky was densely clouded, and though heavy rain fell for a time during the later hours of the day, this outlet was probably insufficient to stay the steady accumulation of aqueous vapour over the enclosed area. In the afternoon of this day (3rd) the *Falls of Garry* in Lat. 5° S. reported the cessation of the south-east trades, their replacement by light, variable, "puffy" breezes and heavy rain. By the 4th the process of accumulation of aqueous vapour had apparently reached its maximum and the subsequent condensation had set in. A continuous downpour of rain was reported, and this was accompanied with light variable airs and calms on all the ships within the enclosed area. At the same time as the constant rapid condensation proceeded so did atmospheric pressure diminish, so that by the morning of the 6th a well-defined central area of depression had been developed within the enclosed area almost directly over the equator. It is interesting to note that, so far as can be judged from the observations, at the period when the process of constant evaporation had resulted in a saturated condition of the atmosphere over the enclosed area, and the subsequent process of sudden, rapid and extensive condensation had succeeded, there apparently occurred a slight but appreciable rise of pressure over the whole equatorial region under observation. This rise was shown by the chart of 8 A.M. of the 4th (Pl. XXXVIII), and it will be remembered that it was after 4 P.M. on the 3rd that the process of rapid condensation set in and became the most important of the changes in progress over the area.

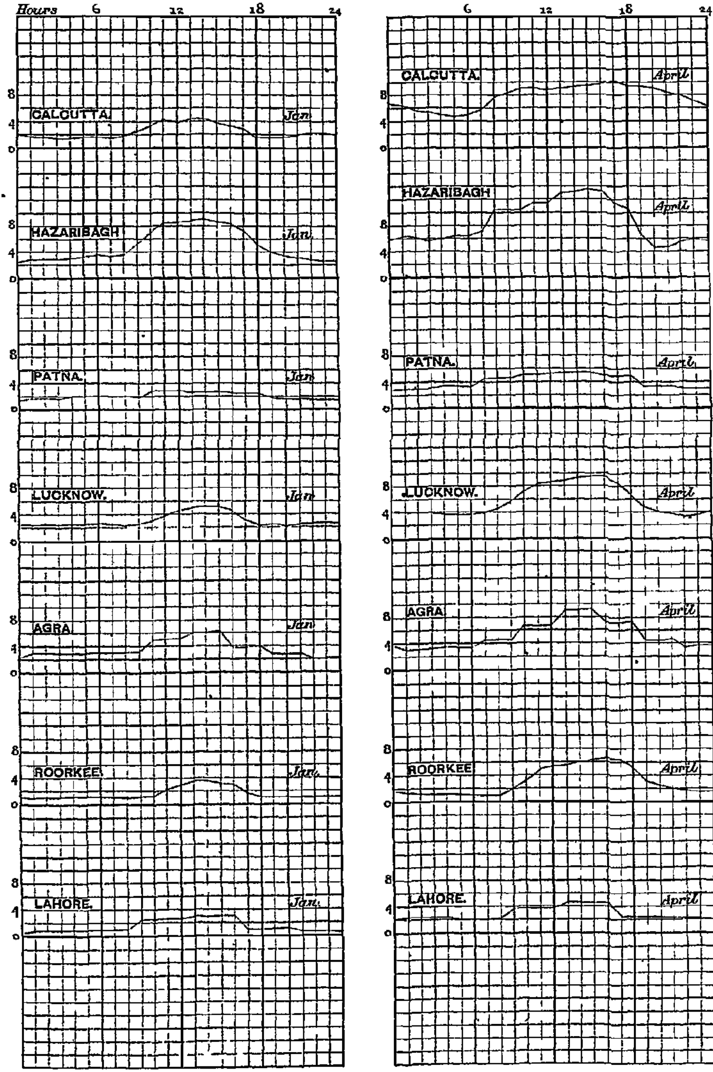
If the above be the explanation of the initiation of the storm, then further enquiry would be unnecessary, as the principle of evaporation and condensation is a general and not a local one and is as applicable to equatorial regions as to other parts of the earth's surface. Further, it is unnecessary from this point of view to introduce a force to account

for the gyratory motions, as the theory presupposes an irregular inflow of the surrounding air as pressure diminishes, an inflow which can only result in a vorticose or spiral motion of the atmosphere converging towards a centre, while for the gradual increase in the intensity of the barometric depression and in the force of the winds an adequate cause is assigned in the rapid condensation and precipitation of rain accompanying the inflowing currents of air when once the centre is developed.

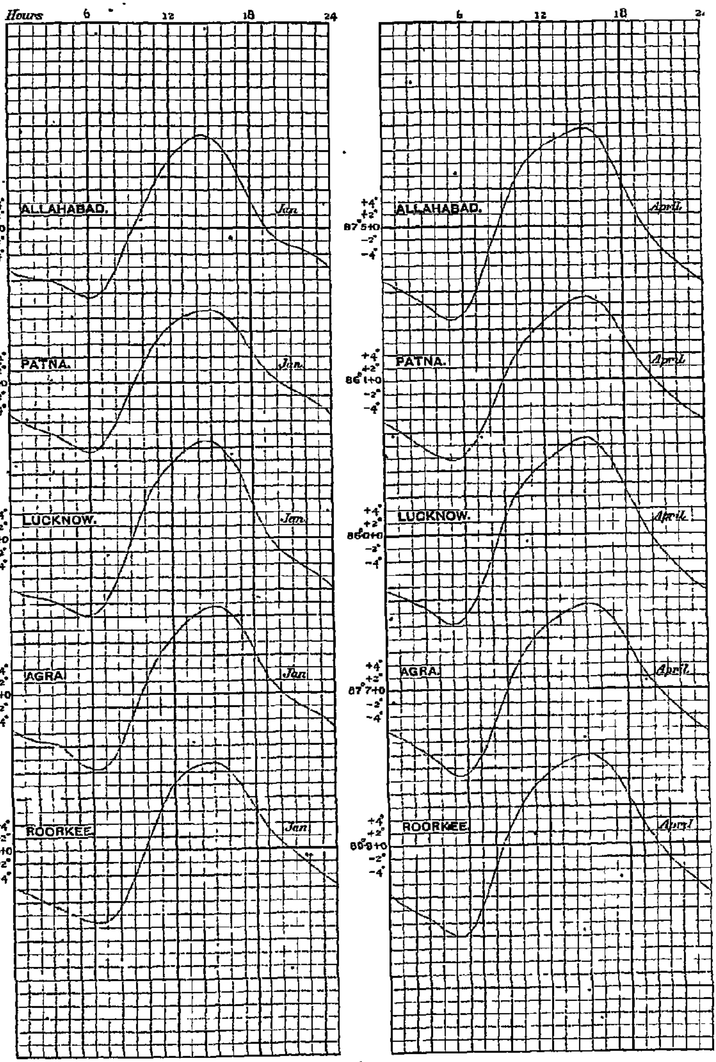
In the preceding pages the writer has attempted to give an account of a very interesting storm and at the same time to discuss the changes attendant on its development and progress from two widely different points of view.

Two minor points of interest connected with the disturbance deserve perhaps passing notice. The first is the torrential rain which accompanied the disturbance throughout its course. This rainfall was apparently associated with a stream of air from trans-equatorial regions, and as soon as this supply was cut off and the wind shifted to north-east again, to the south of the disturbance the rainfall decreased and the intensity of the disturbance diminished. The second is the sharply defined limits of the disturbance. Hardly any indication of the presence of a storm was afforded by the coast observations. So much so indeed was this the case that the rainfall which occurred around the head of the Bay on the 14th and 15th when the centre of disturbance was in Lat. 18° and 20°N was ascribed to disturbed weather in Upper India, instead of to its actual source, *viz.*, the depression over the Bay.

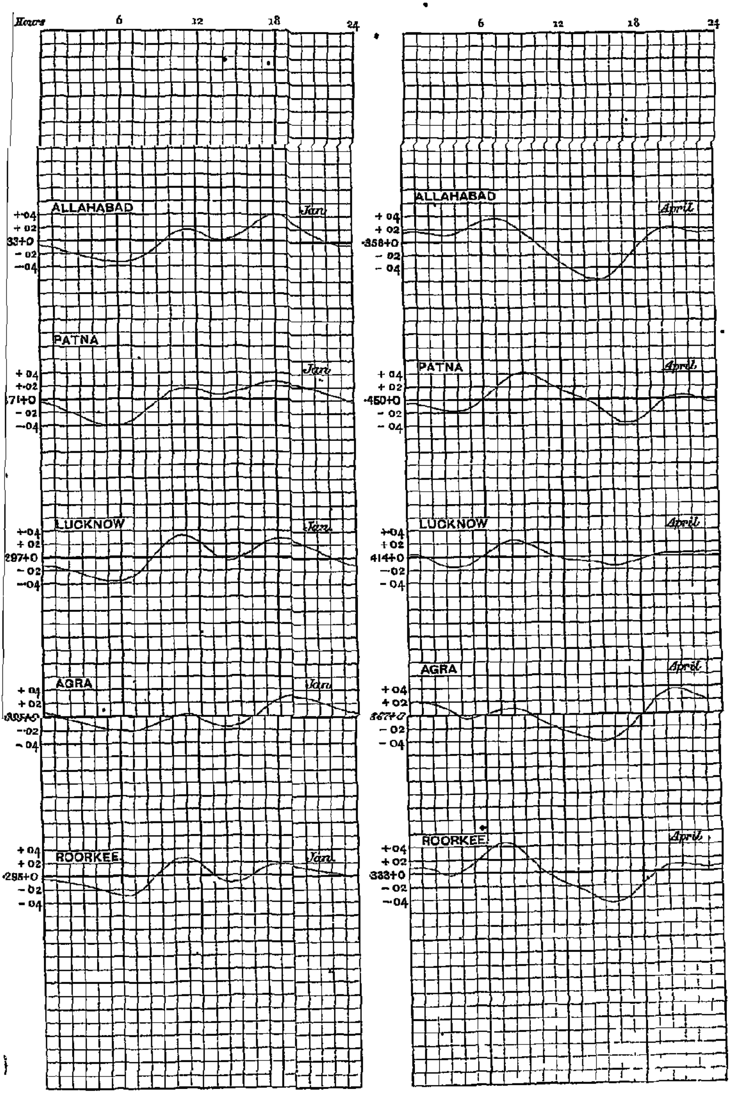
CURVES REPRESENTING THE MEAN DIURNAL VARIATION OF AIR-MOVEMENT AT SEVEN STATIONS IN THE GANGETIC PLAIN FOR THE MONTHS OF JANUARY AND APRIL.

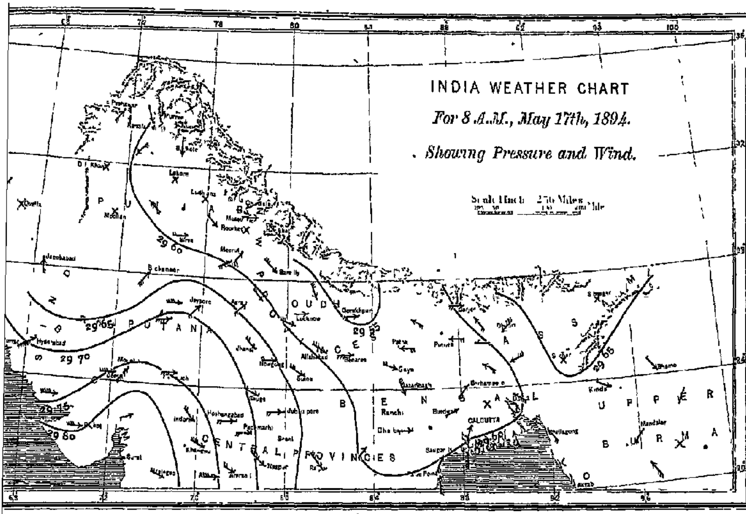


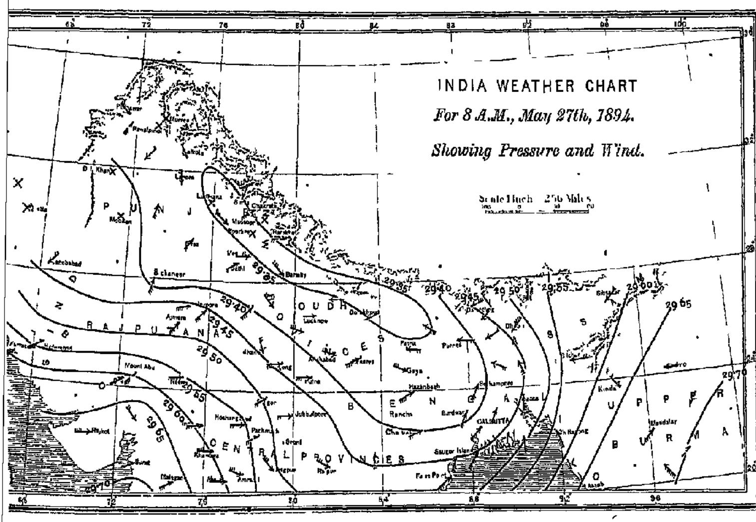
CURVES REPRESENTING THE MEAN DIURNAL VARIATION OF TEMPERATURE AT FIVE STATIONS IN THE GANGETIC PLAIN FOR THE MONTHS OF JANUARY AND APRIL.



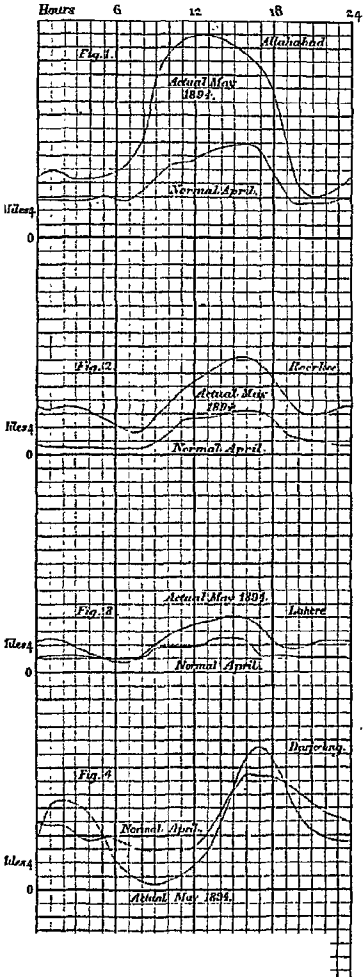
CURVES REPRESENTING THE MEAN DIURNAL VARIATION OF VAPOUR PRESSURE AT FIVE STATIONS IN THE GANGETIC PLAIN FOR THE MONTHS OF JANUARY AND APRIL.



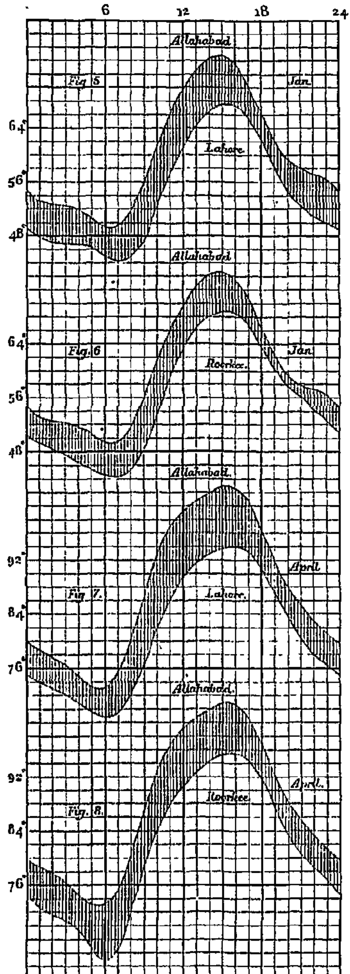

INDIA WEATHER CHART
For 8 A.M., May 17th, 1894.
Showing Pressure and Wind.


INDIA WEATHER CHART
For 8 A.M., May 27th, 1894.
Showing Pressure and Wind.

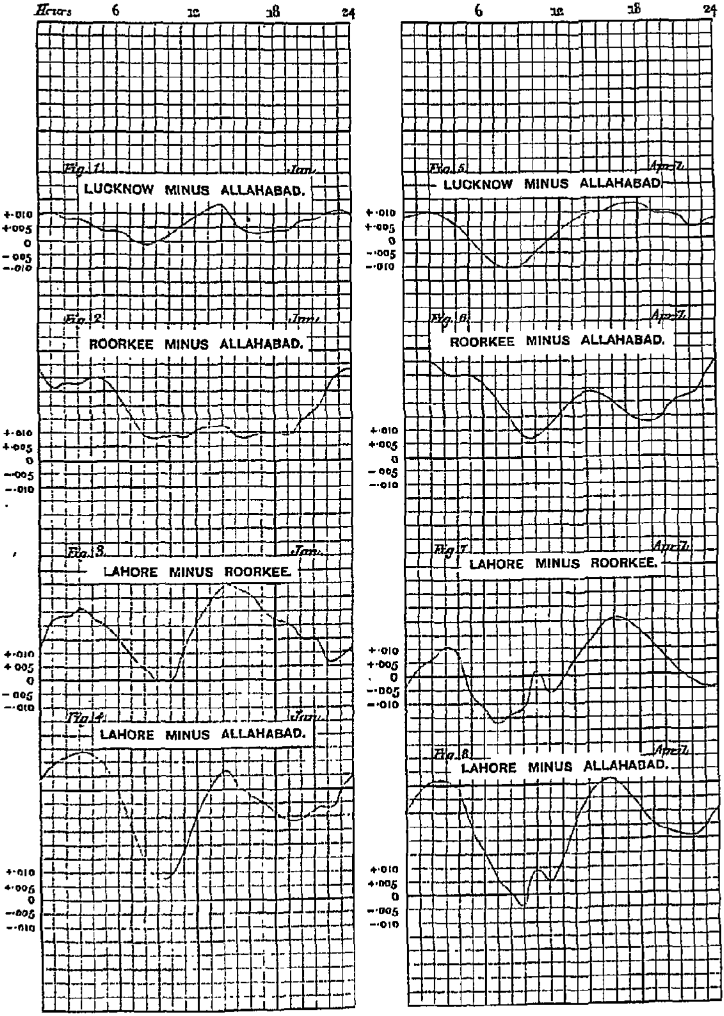
CURVES REPRESENTING THE MEAN ACTUAL AIR MOVEMENT ON SELECTED DAYS IN MAY 1894 AND THE NORMAL AIR MOVEMENT IN APRIL AT CERTAIN STATIONS IN NORTHERN INDIA.



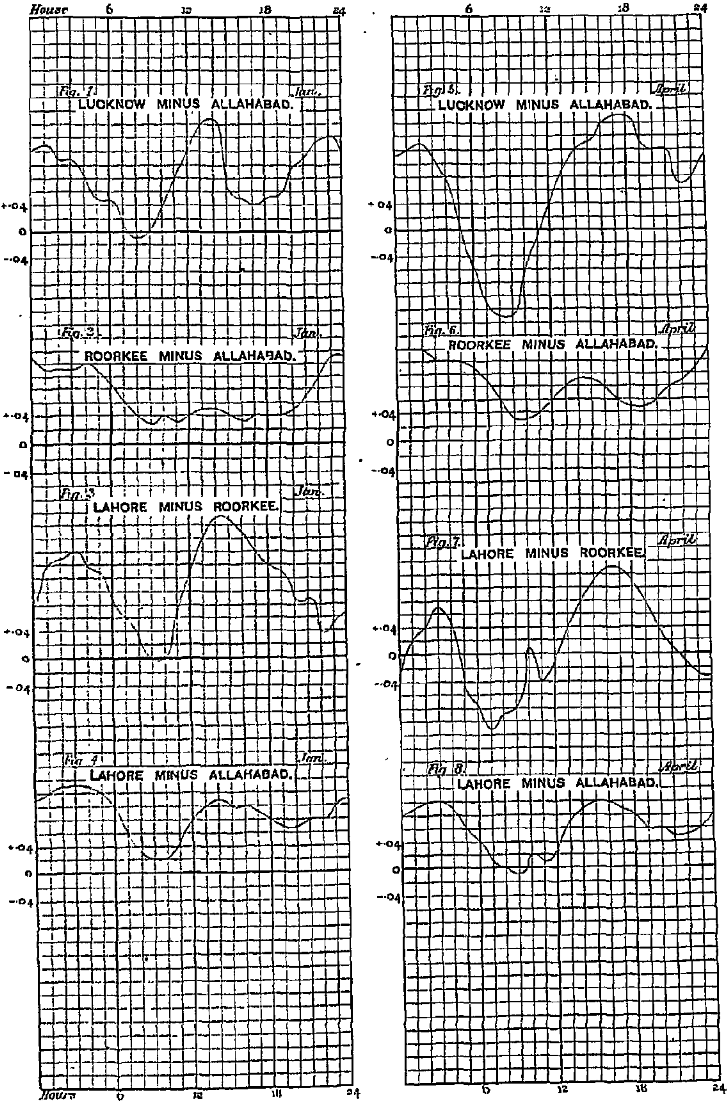
CURVES REPRESENTING THE MEAN HOURLY DIFFERENCES OF TEMPERATURE BETWEEN TWO PAIRS OF STATIONS IN THE GANGETIC PLAIN FOR THE MONTHS OF JANUARY AND APRIL.



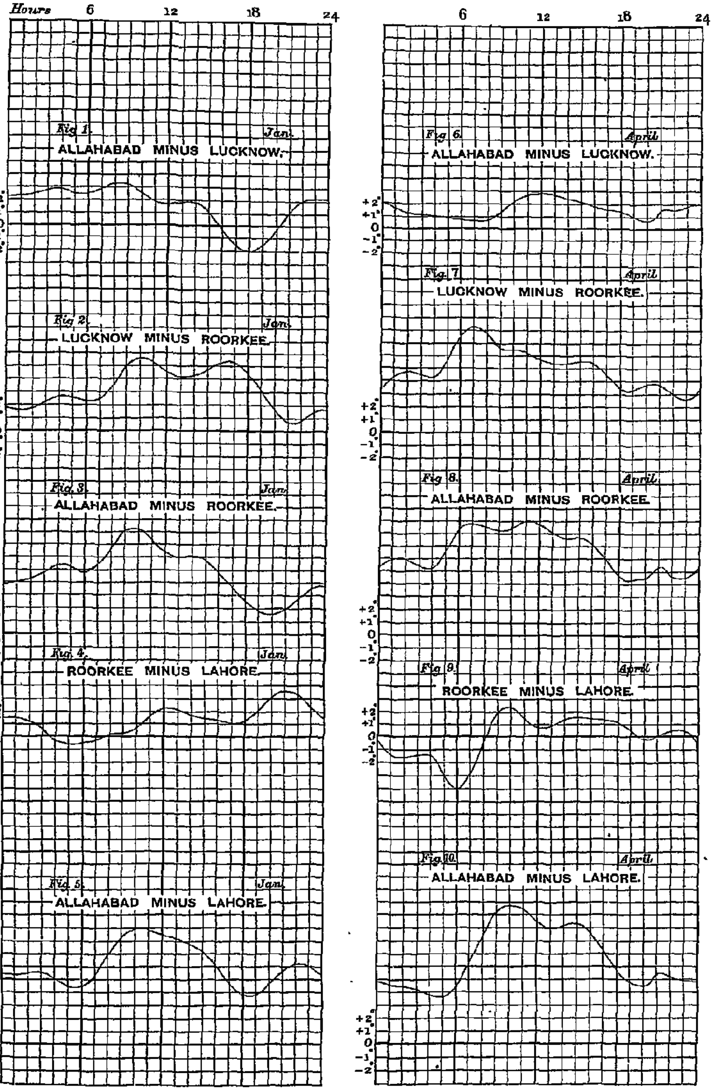
CURVES REPRESENTING THE DIURNAL VARIATION OF DIFFERENCES OF PRESSURE BETWEEN FOUR PAIRS OF STATIONS IN THE GANGETIC PLAIN FOR THE MONTHS OF JANUARY AND APRIL.



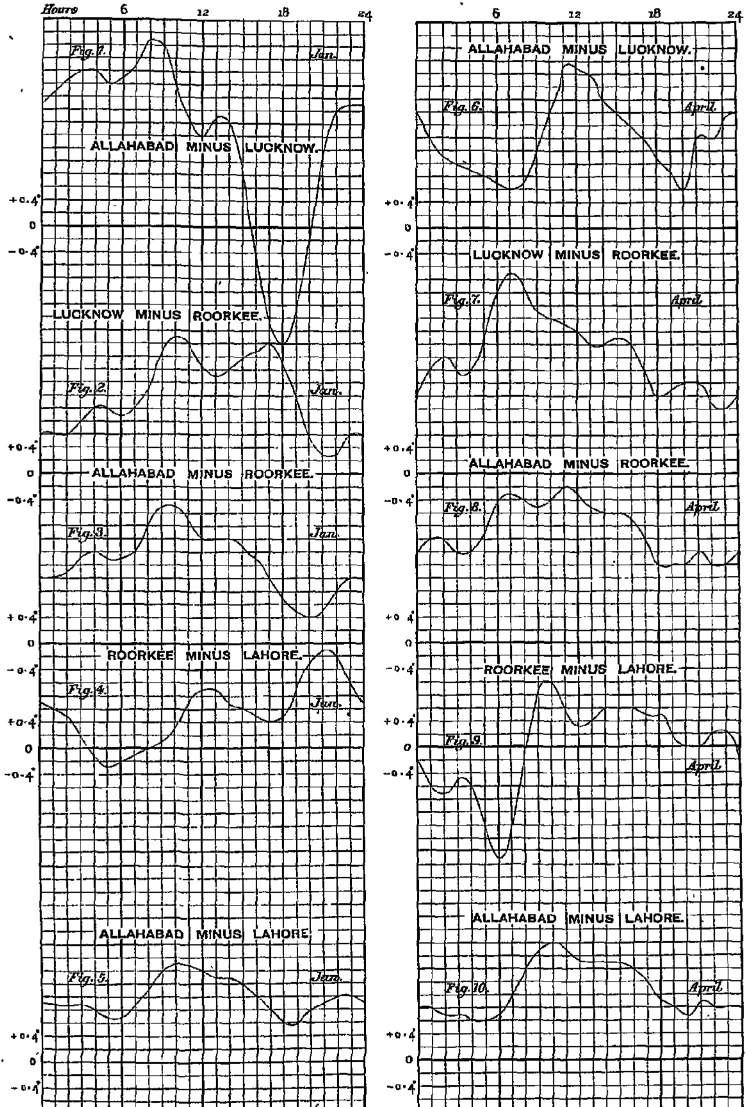
CURVES REPRESENTING THE DIURNAL VARIATION OF PRESSURE GRADIENT (·01 INCH PER 15 GEOGRAPHICAL MILES) BETWEEN FOUR PAIRS OF STATIONS IN THE GANGETIC PLAIN FOR THE MONTHS OF JANUARY AND APRIL.



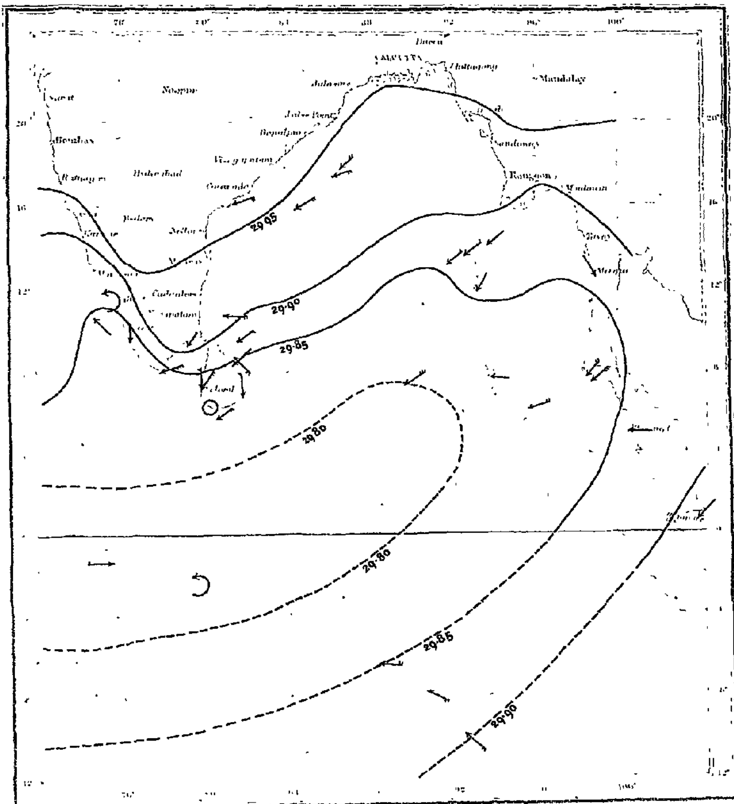
CURVES REPRESENTING THE DIURNAL VARIATION OF DIFFERENCES OF TEMPERATURE BETWEEN FIVE PAIRS OF STATIONS IN THE GANGETIC PLAIN FOR THE MONTHS OF JANUARY AND APRIL.



CURVES REPRESENTING THE DIURNAL VARIATION OF TEMPERATURE GRADIENT (1° PER 100 GEOGRAPHICAL MILES) BETWEEN FIVE PAIRS OF STATIONS IN THE GANGETIC PLAIN FOR THE MONTHS OF JANUARY AND APRIL.

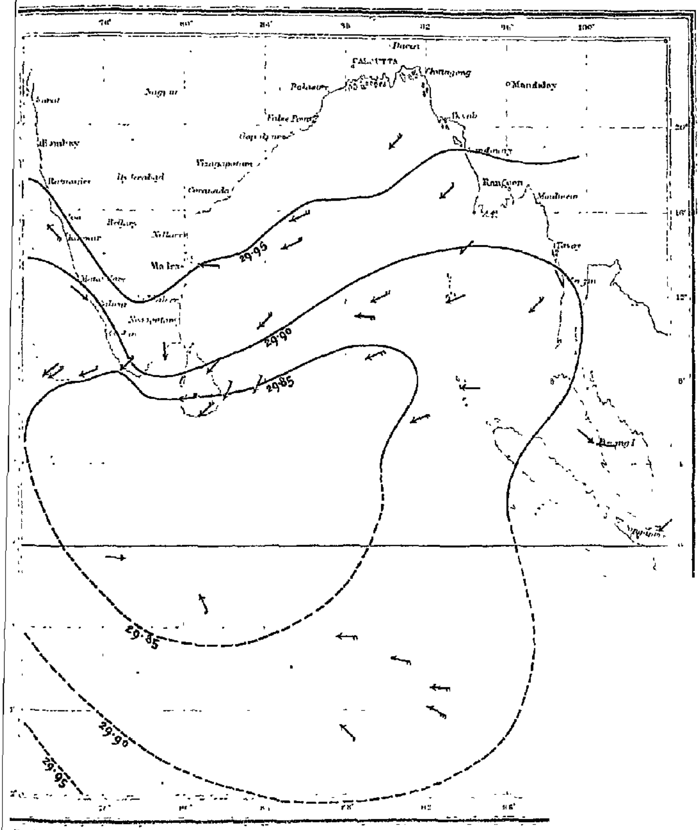


BAY OF BENGAL. DECEMBER 1st, 1894.



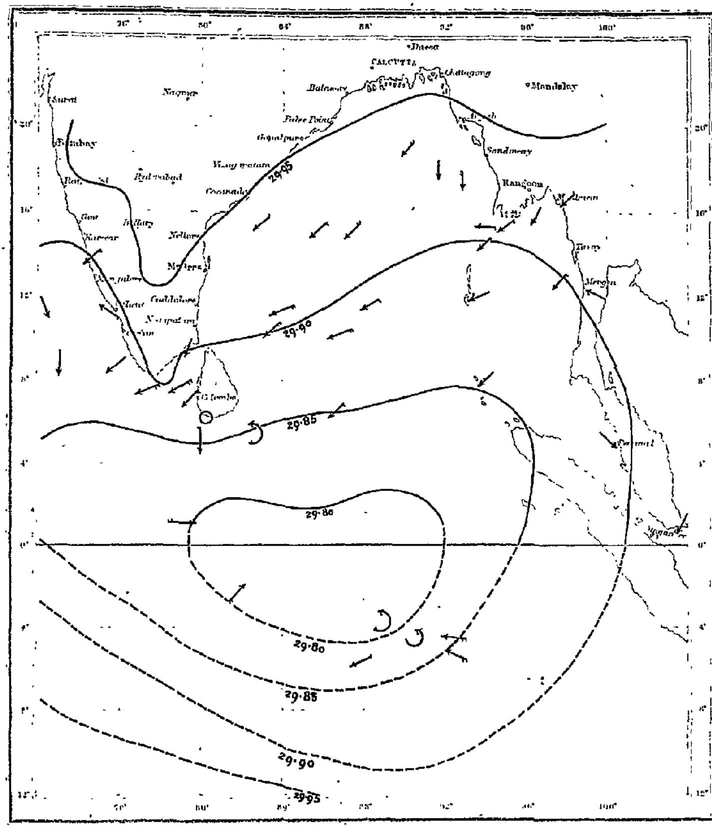
Litho., S. I. O., Calcutta

BAY OF BENGAL. DECEMBER 2nd, 1894.



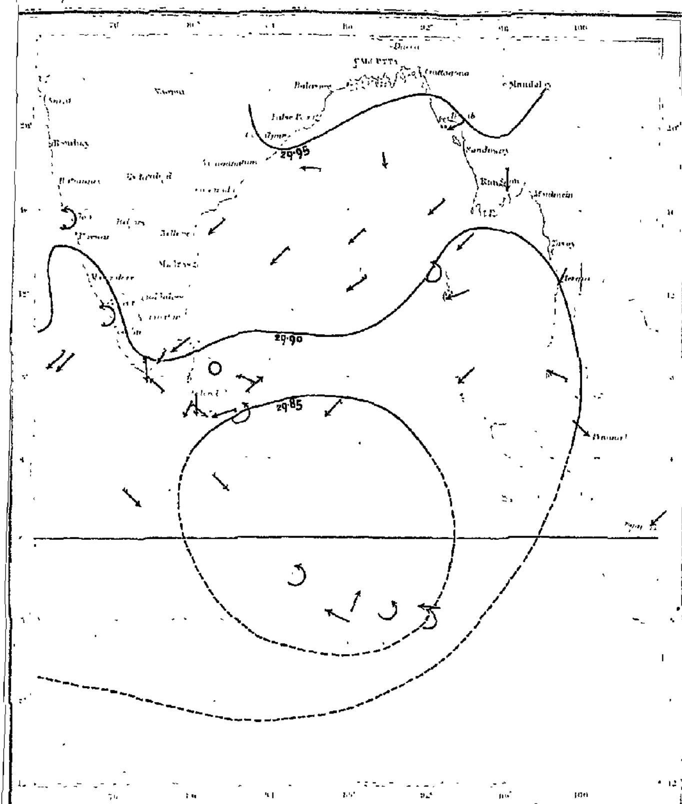
Wind force.	Symbol.
Calm	Circle.
0 to 1	Arrow without feather.
2 to 3	Arrow with one feather.
4 to 5	" " two feathers.
6 to 7	" " three "
8 to 9	" " four "
10 to 11	" " five "
12	" " six "
Variable.	↻

BAY OF BENGAL, DECEMBER 3rd, 1894.



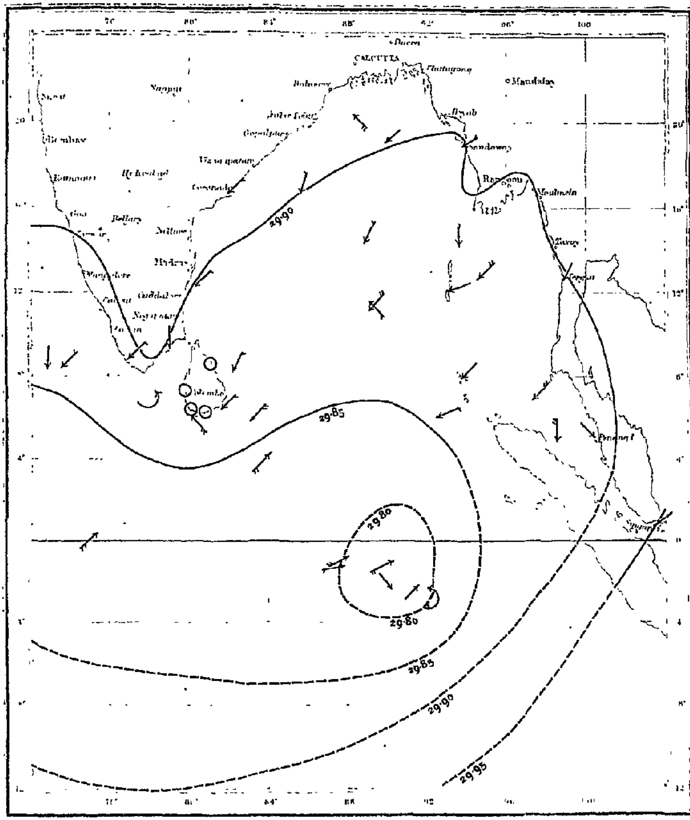
Wind force.	Symbol.
Calm	Circle.
0 to 1 ...	Arrow without feather.
2 to 3	Arrow with one feather.
4 to 5	" " two feathers.
6 to 7	" " three "
8 to 9	" " four "
10 to 11	" " five "
12	" " six "
Variable.	◡

BAY OF BENGAL. DECEMBER 4th, 1884.



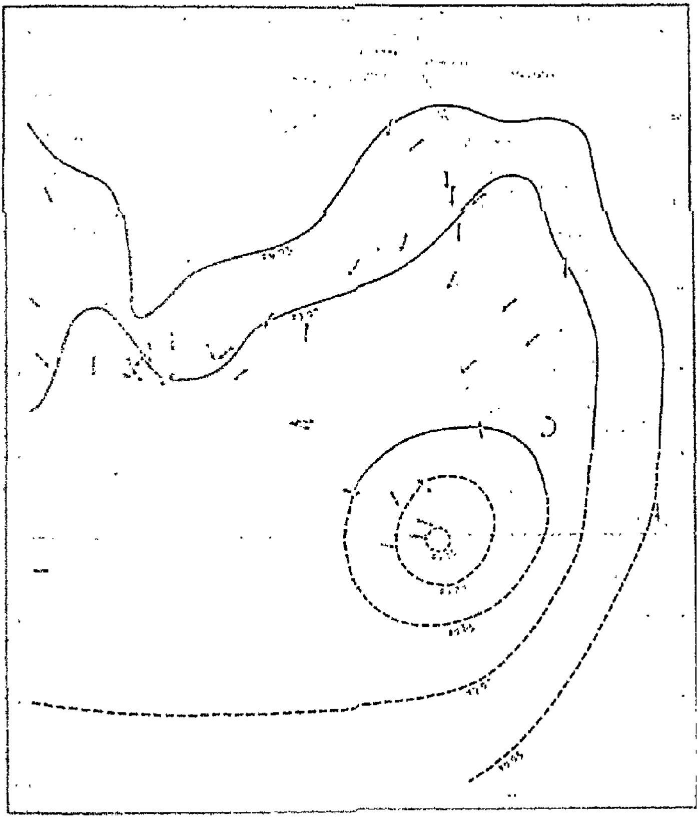
Wind force			Symbol.		
Calm	...	...	Circle.		
0 to 1	...	...	Arrow without feather.		
2 to 3	...	...	Arrow with one feather.		
4 to 5	...	...	„	„	two feathers.
6 to 7	...	...	„	„	three „
8 to 9	...	...	„	„	four „
10 to 11	...	...	„	„	five „
12	...	...	„	„	six „
Variable.			↻		

BAY OF BENGAL. DECEMBER 5th, 1894.

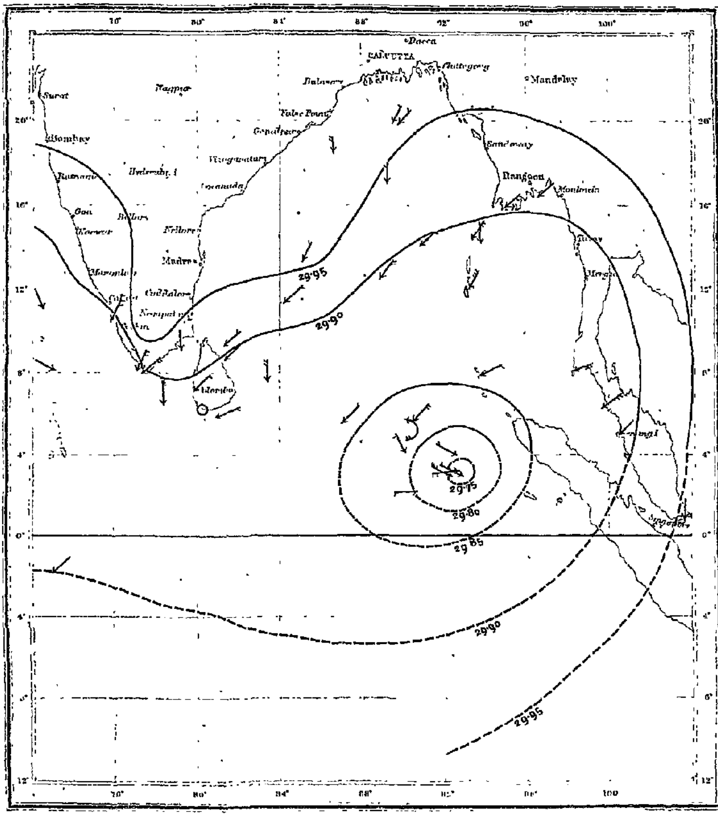


Wind force.	Symbol
Calm	Circle.
0 to 1	Arrow without feather.
2 to 3	Arrow with one feather.
4 to 5	" " two feathers.
6 to 7	" " three "
8 to 9	" " four "
10 to 11	" " five "
12	" " six "
Variable.	↻

BAY OF BENGAL, DECEMBER 6th 1894

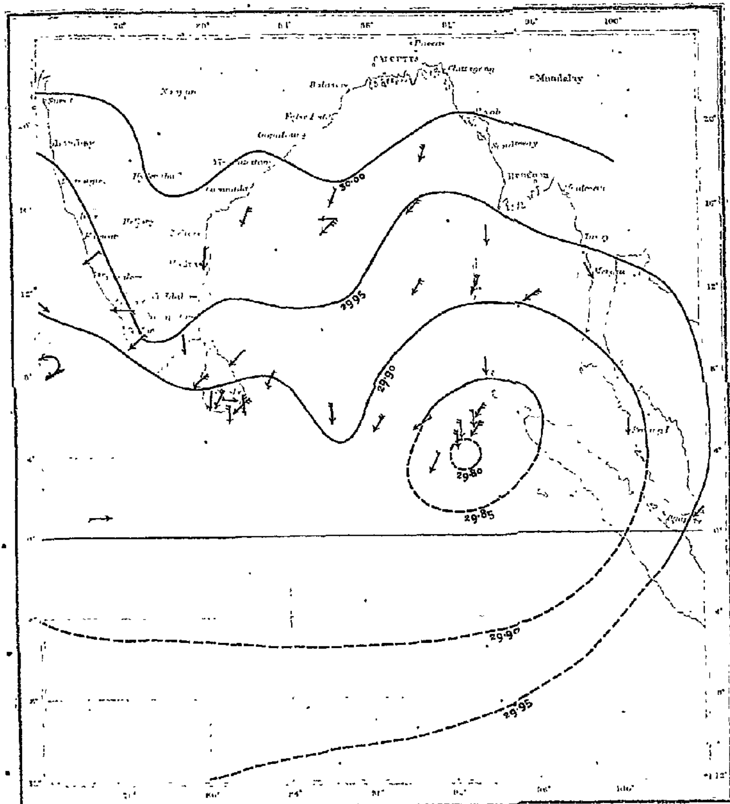


BAY OF BENGAL, DECEMBER 7th, 1894.

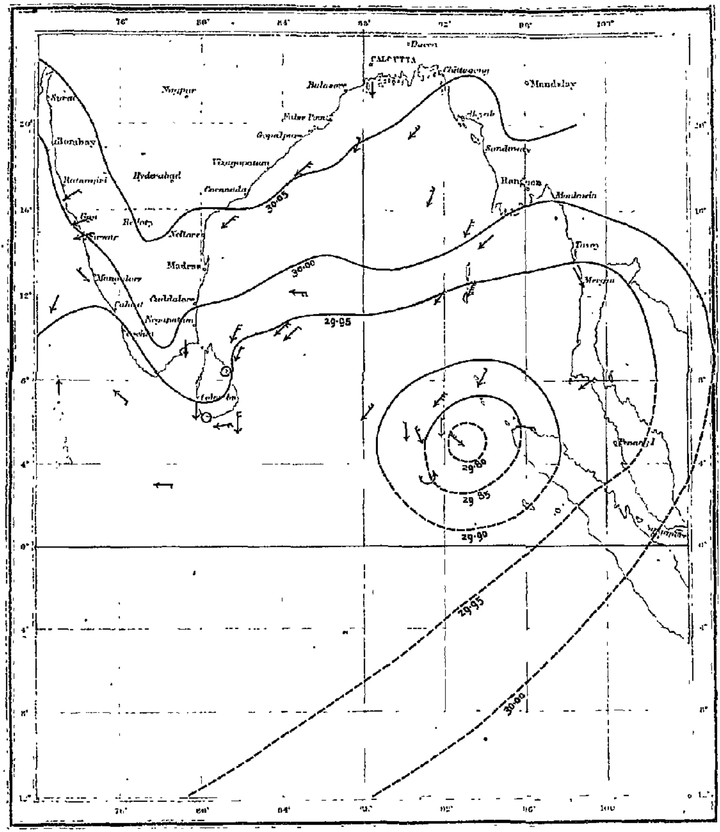


Wind force	Symbol.
Calm ..	Circle.
0 to 1 .	Arrow without feather.
2 to 3	Arrow with one feather.
4 to 5	„ „ two feathers.
6 to 7	„ „ three „
8 to 9	„ „ four „
10 to 11 . ..	„ „ five „
12	„ „ six „
Variable.	↻

BAY OF BENGAL, DECEMBER 8th, 1884.

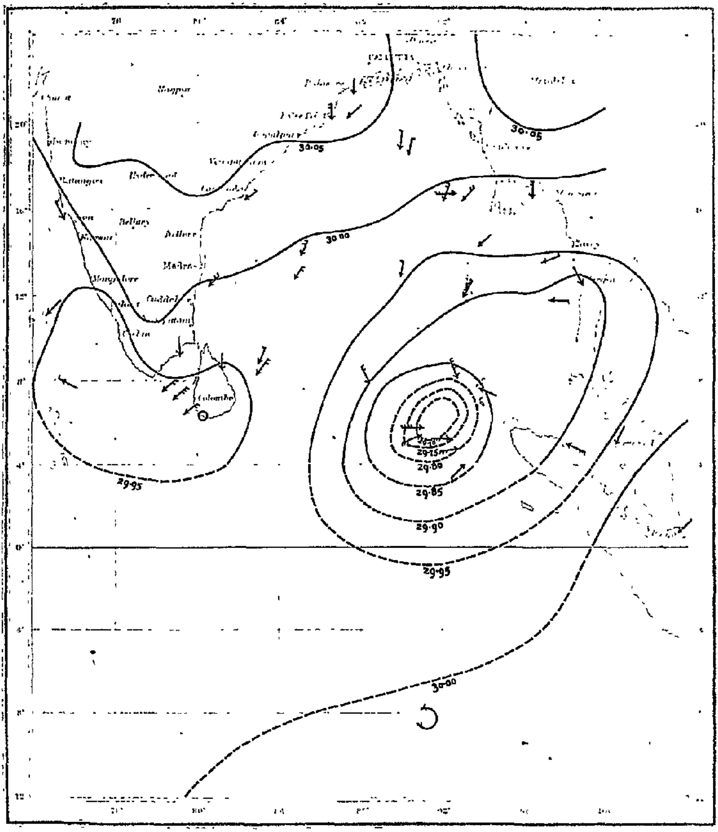


BAY OF BENGAL.-DECEMBER 9th, 1894.



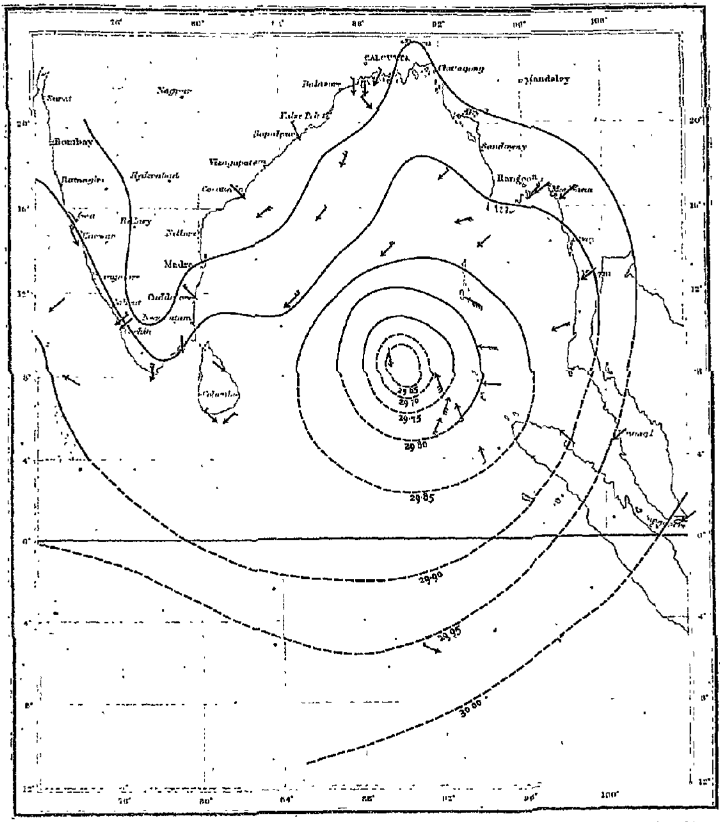
Wind force.			Symbol.
Calm	...	...	Circle.
0 to 1	...	..	Arrow without feather.
2 to 3		...	Arrow with one feather.
4 to 5	...	...	,, ,, two feathers.
6 to 7	...	...	,, ,, three ,,
8 to 9	...	...	,, ,, four ,,
10 to 11		...	,, ,, five ,,
12	...	...	,, ,, six ,,
Variable			

BAY OF BENGAL,—DECEMBER 10th, 1884



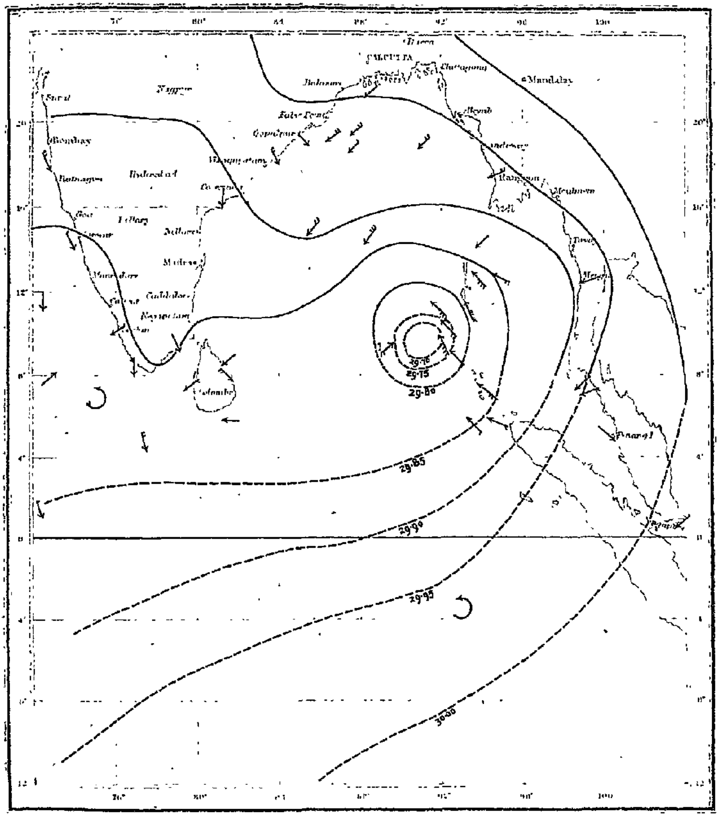
Wind force.	Symbol
Calm	Circle
0 to 1 ...	Arrow without feather.
2 to 3	Arrow with one feather.
4 to 5	" " two feathers.
6 to 7	" " three "
8 to 9	" " four "
10 to 11	" " five "
12	" " six "
Variable	↻

BAY OF BENGAL.—DECEMBER 11th, 1894.



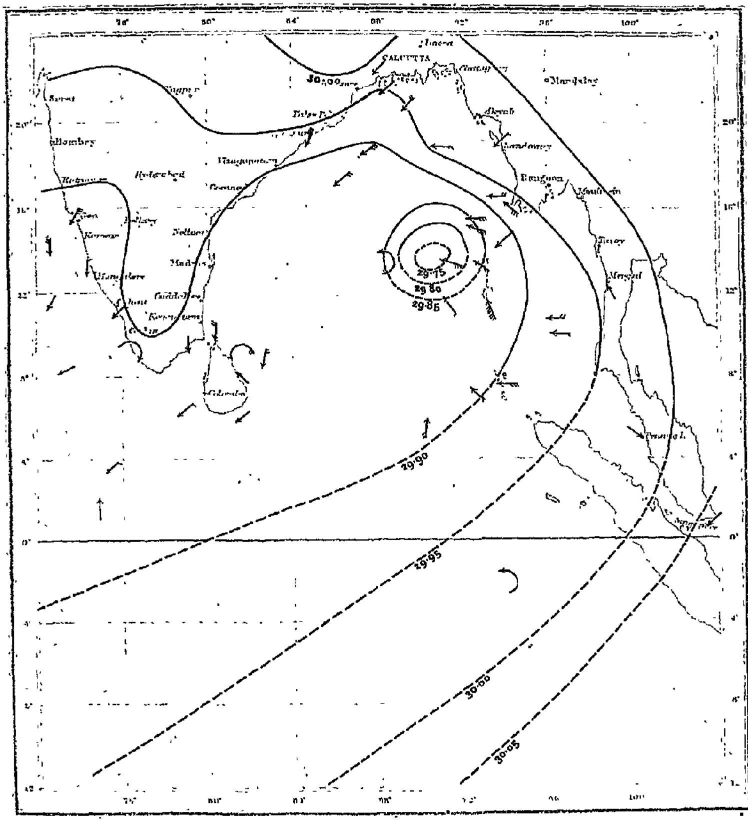
Wind force.			Symbol.
Calm	..	...	Circle.
0 to 1	....	...	Arrow without feather.
2 to 3	..	...	Arrow with one feather.
4 to 5	...	...	,, ,, two feathers.
6 to 7	...	...	,, ,, three ,,
8 to 9	..	...	,, ,, four ,,
10 to 11	.	...	,, ,, five ,,
12	...	...	,, ,, six ,,
Variable.			↻

BAY OF BENGAL—DECEMBER 12th, 1894.

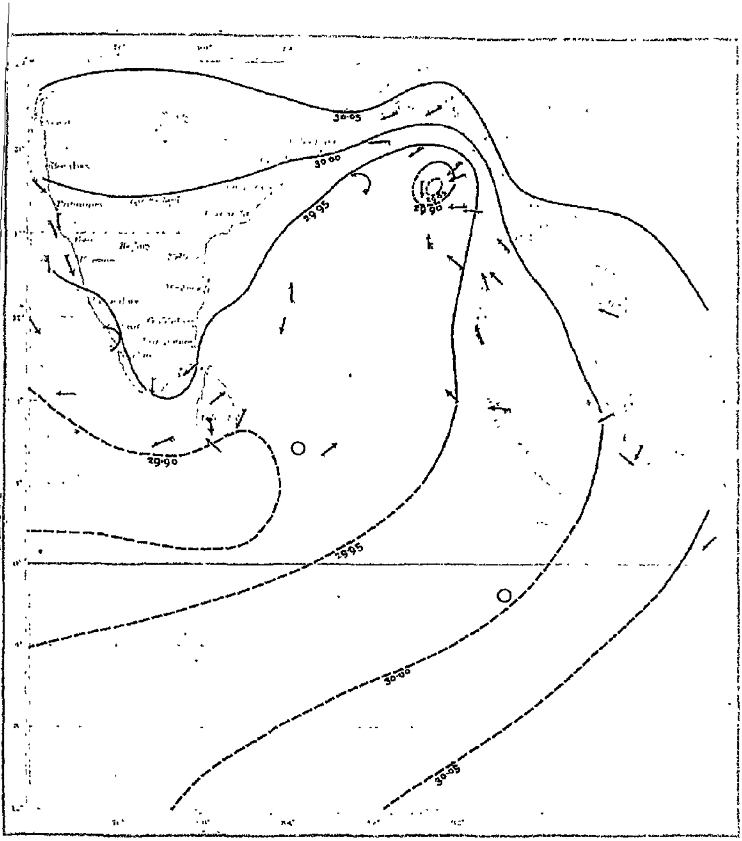


Wind force.	Symbol.
Calm ..	Circle.
0 to 1 ..	Arrow without feather.
2 to 3	Arrow with one feather.
4 to 5	„ „ two feathers
6 to 7	„ „ three „
8 to 9	„ „ four „
10 to 11	„ „ five „
12	„ „ six „
Variable.	

BAY OF BENGAL.—DECEMBER 13th, 1894.



Wind force.	Symbol.
Calm	Circle.
0 to 1 ..	Arrow without feather
2 to 3 .	Arrow with one feather
4 to 5	„ „ two feathers.
6 to 7	„ „ three „
8 to 9	„ „ four „
10 to 11	„ „ five „
12	„ „ six „
Variable.	↻



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30·00
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29·90
29·90
29·95
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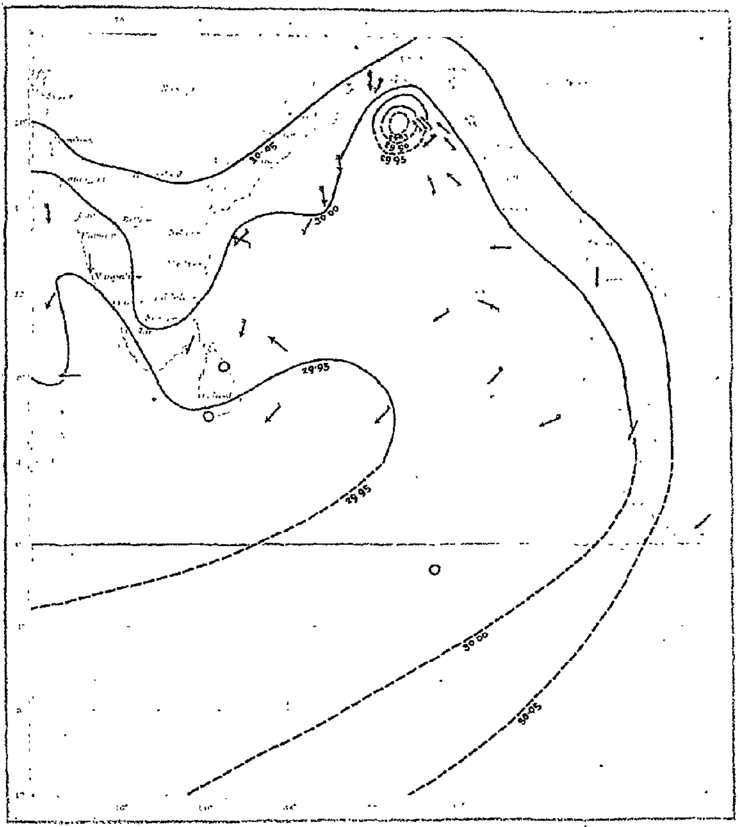
30·05



30·05
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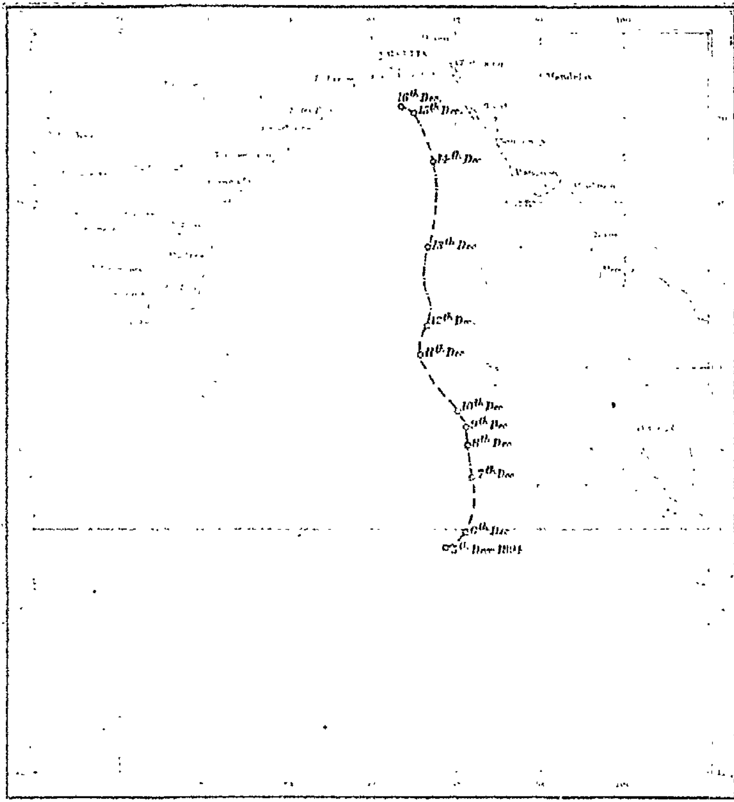
TRACK OF THE STORM IN THE BAY OF BENGAL—DECEMBER 6th TO DECEMBER 16th, 1894.



WIND DIRECTIONS RECORDED DURING THE STORM IN THE BAY OF BENGAL—DECEMBER 1894.